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SMITHSONIAN INSTITUTION.
UNITED STATES NATIONAL MUSEUM.

INSTRUCTIONS FOR COLLECTING MOLLUSKS, AND OTHER USEFUL HINTS FOR THE CONCHOLOGIST.

BY

WILLIAM H. DALL,
Honorary Curator of the Department of Mollusks, U. S. National Museum.

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INTRODUCTORY.

Invertebrates of the molluscan type are found in all parts of the world and in nearly every situation. The highest mountains, the widest prairies, the least accessible oceanic islets, and even the desert of Sahara and the frosty moss of Arctic tundras, afford specimens of mollusks on careful and intelligent search.

For the purposes of the collector the group may be divided into three classes, including, respectively, land, fresh-water, and marine species. Each of these classes requires special treatment and will be discussed separately. Every land area which borders on the sea and contains permanent bodies of fresh water will be found to support representatives of each class. Geologically, each goes back to a remote antiquity.

LAND SHELLS.

From the standpoint of the collector this class includes gastropods both of the pulmonate and gill-bearing types, forms which are united in the amphibious *Siphonaria*, which possesses both gills and a true lung. They may be limpet-shaped or spiral; operculate or inoperculate; shell-bearing or naked; herbivorous or carnivorous.

HABITAT AND STATION.

They are found at all elevations, from the beaches moist with sea spray to the alpine heights of 14,000 feet in the vicinity of perpetual snow. Some, like *Testacella*, are subterranean in their habits, pursuing earthworms through their burrows and never visiting the light of day; or nestling in the cancellated recesses of bones in ancient graveyards (*Acicula*) where they browse on fungoid mycelium. Others are contented with the protection afforded by dead leaves, decaying logs, under the bark starting from rotting stumps, or in the shelter of loose stones and bowlders. Other groups live on the leaves of sedges, grass, and shrubbery, retreating to the soil for winter quarters; while in the

lofty tree tops of tropical forests still others live permanently, never visiting the ground, and, in their airy domicile, exhibit colors almost as varied and brilliant as the arboreal flowers which surround them. In arid regions some seek the shade of stones or attach themselves to the stems of cacti or other desert plants, while others again adhere to the sunburnt surfaces of rocks so hot as to be uncomfortable to the touch, on which their white or rusty shells stand out conspicuously. It has been generally noted that the color of the shell bears a certain relation to its favorite station, the arboreal forms presenting the brightest and most varied colors; the moss lovers and terrestrial species being usually dull, horny, or greenish, though often with a brilliant, polished, or delicately sculptured surface; while subterranean forms are usually pale or pellucid. The slugs are usually nocturnal in their habits, retreating to holes and crevices at dawn; the cultivator, whose succulent vegetables they destroy, seeing his harvest ravaged without a visible enemy. On one of the Florida keys, built of the debris of coral, and as full of holes and crevices as a sponge, a settler raising early tomatoes for the New York market found to his dismay as the fruit began to ripen that every red one was immediately eviscerated, leaving nothing but the skin. There were no birds, worms, or mice to do such damage, which was not occasional but general over his whole farm. Finding nothing by day he took to scrutiny by night and was rewarded by the discovery of myriads of slugs which proceeded from the interstices of the coral and devoured every ripe fruit. The plague admitted of no remedy, the enemy was too numerous, and the unfortunate cultivator was obliged to abandon his undertaking and go into bankruptcy, ruined by *Veronicella*.

In general, limestone regions are most favorable for land shells and those of flinty rock least advantageous. Woods of coniferous or resinous trees are unsuited to their tastes, while those of deciduous soft wooded nature offer a congenial home for the mollusks. Certain pungent herbs, especially cruciferæ, are said to be obnoxious to slugs. Gardeners in Europe are said to protect their lettuce beds by a hedge of mustard or pepper grass. Nettles, on the other hand, are a favorite haunt of certain small land shells. Dry coal ashes, alkaline wood ashes wet or dry, sand and lime in a pure state, are more or less effectual in repelling the slugs, which they irritate mechanically. It is probable as far as the smaller species are concerned that the unfavorable nature of resinous trees is due more to the fact that they decay less easily and afford a less favorable nidus for fungi upon which the snails feed than to any direct influence of the resin upon the mollusks. Salt is inimical to most of the *Helicidæ*, but the *Auriculidæ* or many of them, *Truncatella* and *Polygyra*, seem to prefer the vicinity of the sea.

Spring is the most active season for snails as for most animals, they attain their fullest development toward midsummer, and as winter approaches they penetrate the ground or in warm regions attach them-

selves to the bark of trees or to stones for a period of hibernation. They close the aperture of the shell with a leathery secretion, sometimes strengthened by more or less limy matter, or if naked may surround themselves with it like a cocoon. This temporary defense, common to most of the inoperculate forms, is called the epiphragm, and, in the many whorled species, there are often several of these partitions between the retracted animal and the aperture of its shell. In the arboreal Bulimi the secretion is often of great strength, and the collector who finds them fastened to trees and attempts to pull them off will often see the shell or the bark break before the epiphragm will give way. In such cases it is better to cut off a thin slice of the bark with the adherent shell. On an immersion in warm water the mollusk will awake and soon release itself in the natural way. It is the habit of many snails on waking from their hibernation to make their first repast on their own epiphragm. The period of attachment is often marked by a band of color in harmony with the lines of growth, not elsewhere repeated on the shell, and usually bluish or dark brown. This indicates the formation of a special secretion at such times. The life of most land shells is probably short, a majority probably do not live more than a year or two, though, under suitable conditions, there would seem to be no reason why this period should not be much prolonged. The species of arid regions become accustomed to long periods of enforced hibernation and are the longest lived. Instances are known of their surviving four or five years without food in this state, and it is a common thing for them to survive transportation through long sea voyages to distant countries. These facts have an important bearing on their distribution. There would seem to be no doubt that in some cases the ancestors of a land shell fauna have reached oceanic islets by drifting on vegetation dislodged by freshets and carried out to sea, especially in the warmer regions.

COLLECTING OUTFIT.

The collector of land shells needs only a very simple and inexpensive outfit. For most purposes, in temperate and northern regions, the things needed may be easily carried in one's pocket. First in point of usefulness is a pair of spring forceps, which should have a delicate spring requiring no sensible exertion to make the points meet. The points themselves should be slender and the file cutting on their inner sides should not be coarse. These forceps, which any surgical instrument maker should furnish at a cost of $1 or less, are indispensable in collecting the more minute forms, for which the fingers are far too clumsy. After a little practice the most minute *Vertigo* or *Hyalinia* may be picked up without injury, though the beginner is apt to crush a goodly number before he learns the necessary delicacy of manipulation. The forceps come into play almost as much in separating the day's collections as in making them; in fact, after a little, one feels lost without them.

Two or three stout homeopathic vials, with good long corks, may be put in the vest pocket. A thread may be put through the top of the cork and tied to the neck of the vial, thus obviating the necessity for hunting a dropped cork in the underbrush, or a few spare corks may be carried. Either method is preferable to delay and possible loss of temper when collecting is good.

A couple of wide-mouthed two-ounce bottles, with strong corks, will serve for somewhat larger species, while for snails of the size of *Helix albolabris* wooden pill boxes, or small tin boxes, such as mustard or yeast powder is put up in, will be found convenient. A little cotton or moss should be put in the bottom of the box before it is used for shells.

If it is desired to study the living animals the vials or boxes into which the specimens are dropped should be dry and clean, but for ordinary collecting it will be found more convenient to have the vials for small species half filled with alcohol diluted with one third its volume of water. This alcohol abstracts the moisture from the soft parts, so that they may be dried afterward without making an offensive odor, and prevents the snails from adhering to each other and to the glass, which otherwise they are very apt to do, when it is difficult to separate them or get them out of the vial unbroken. The larger species do not need this precaution and may be treated later, at home. For collecting the minute *Pupidæ* and similar species a small net is very convenient. This should be made of stout (say ¼ inch) steel or brass wire, circular, with a projection fitted to screw into a socket fastened to a stout cane or stick. The frame may be permantly fastened to the stick if preferred and should be 10 or 12 inches in diameter. The net may be made of brown linen or cheese cloth in the form of a cone sewed over the frame at its base, and should be twice as long as the diameter of the frame. The coarse grass and high sedges of moist places, on which the little mollusks love to creep up, may be beaten with the net, into which they fall, and afterward the net turned inside out over a newspaper, the larger rubbish rejected and the remainder shaken into a box to be examined at leisure. The moist leaves which collect on the ground where meadow and woodland meet may be put into a sack, taken home, dried, well shaken, and the dirt collected from them when picked over will often afford large numbers of the minute species in which the collector delights. Loose moss from favorable localities may be treated in the same way and will often well repay the trouble.

Over most of the United States no further equipment is necessary for collecting land shells, but if the collector is in a particularly rich field where the larger species abound it may be convenient for him to take a garden trowel for digging in the soft earth under fallen logs, and a miniature pick with one end hatchet-shaped, such as are used for trimming ice by housekeepers. The latter he will find convenient in prying off the bark from stumps and fallen logs, the surface of which, as well

as that of the log itself, should be closely scrutinized as a favorite retreat of *Hyalinia*, *Pupa*, *Vertigo*, and other small species. With good eyes no hand lens should be necessary, but occasionally a collector will find it of use, and one of the cheap triplets with rubber frames, if carefully selected, will be found quite as efficient as the expensive achromatic lenses mounted in German silver which the optician is so prone to recommend.

LOCALITIES FAVORABLE FOR COLLECTING.

The margins of brooks and ponds, the under surface of old weather-worn bits of board, leather or bones such as every pasture affords, the earth around rotten stumps and under fallen logs or flat stones, the moist moss near rocks and especially under overhanging ledges, or in marshes, and in general all cool, moist places where decaying, not resinous, vegetation may afford food and shelter for his prey, will be found worth searching by the collector. The fine debris left by freshets along the borders of streams will often yield many small land shells in good condition if carefully searched. In the tropics Morelet has observed that land mollusks are more or less nocturnal. During the day it is necessary to seek them in their retreats under stones, logs, dead leaves, or in the crevices of rocks, unless the atmosphere is moist enough to induce them to remain abroad. During the heat of the day the imbricated leaves of aloes or agaves often hide snails which protect themselves thus from the sun. One may even set traps in the form of fagots, flat stones, pieces of wood or logs, especially in meadows or prairies, where the snails will take refuge during the heated hours of the day. Some mollusks have peculiar habits, as in the case of a little Algerian helix, which, during the day, buries itself in the loose sand to a depth of several inches, or until it reaches a moist stratum. Some forms, like *Strophia* in the Antilles, seem to enjoy places where they are exposed to the full glare of the sun. These usually have heavy whitish shells. There are, however, no rules so absolute in such matters as to be without exception. Certain little snails live permanently on the dry, harsh leaves of palms and palmettos or the hispid stalks of tall ferns. In general, whatever the soil, hilly or mountainous regions are the most prolific in snail life unless too arid, but a certain number seem to prefer the salty moist air of the borders of the sea and these seldom hibernate. The meadows should not be absolutely neglected, especially in the rainy season. Many small Bulimi prefer to reside there and may be found on the stalks of coarse grasses, often in multitudes. Forests are more prolific, especially in clearings and places where the light may penetrate. When the trees stand in marshy places or are subject to overflow, mollusks are less numerous, but multiply where the soil is more or less broken by masses of rock. They are more abundant in broken and irregular woods than when the trees extend uniformly over level ground. In many regions magnificently colored snails live in the tree tops, where

they are only accessible by climbing or cutting down the trees. It is said that Cuming, the celebrated collector in the Philippine Islands, maintained a corps of several hundred natives constantly occupied in cutting down trees for the purpose of obtaining the fine *Helicidæ*, for which the forests of that region are renowned.

EGGS.

Most terrestrial mollusks lay eggs which are covered with a pellucid membrane, a white and leathery or even a solid calcareous shell, like that of a tortoise egg. These eggs may be found in the haunts of the mollusks themselves, most commonly in cool, moist places. Those of American *Helicidæ* are usually white, translucent, and associated together, though not deposited in a mass. *Bulimus* lays eggs that usually have a calcareous shell. The *B. ovatus* of the Antilles has an egg-shell half an inch in length, in which the young mollusk develops, emerging with several whorls of its spire completely formed and differing from the adult only in size. The amphibious *Ampullaria* lays its eggs on the the stalks of plants growing in marshy places, to which they adhere by an abundant secretion of a partly calcareous nature, which, when dry, forms a brittle animal cement. In *Stenogyra* the eggs may be seen through the translucent shell and apparently are only discharged when ready to hatch. They are so nearly the full size of the caliber of the whorl, that it is astonishing how they can, together with the soft parts, be contained in it. The oviposition and biography of reproduction in many species are entirely unknown. By careful and patient observation the collector has it in his power to add largely to the sum of our knowledge in this particular.

ENEMIES OF LAND SHELLS.

As it is often advantageous for the collector to know the enemies of the objects of his search, a word or two on that point may be in place here. The chief enemies of land mollusks are birds and small mammals, mice, shrews, etc. In North America the birds seem to pay less attention to snails and slugs than do their analogues in Europe. Still the thrushes, blackbirds, and some water birds make use of them for food. A singular sausage-shaped parasite, of which one end is attenuated into a slender tube, is found in *Succinea*. The soft parts of snails thus affected are much distorted. The parasite is one phase of a *Distoma* or fluke-worm, and is of a dark brown color and over an inch in length. It is known as *Leucochloridium americanum* Dall. An analogous species has been described from French Succineas, which is of a mottled green. This parasite attains its development in the intestines of thrushes which feed on the *Succinea*, and may perhaps be fatal to these birds. Smaller Distomas are found in certain species of *Limnæa*, and develop into the liver-fluke, so fatal to sheep. The mollusks are eaten, with the grass upon which they rest, by the sheep, which also eat in the same way large numbers of Helices in Britain, and are said

to fatten upon them. In America we have no species of snail which lives in such numbers among the herbage as do the British forms alluded to. Birds usually destroy the shells of the snails upon which they feed, and so are injurious to collectors. But *Glandina*, a carnivorous snail common in the Southern States, swallows the smaller Helices whole and digests the soft parts at leisure, as the walrus does with sea snails. As many as a dozen specimens of *Polygyra* have been extracted from the gullet of a single *Glandina*. Many of the snails of the type of *Zonites* are carnivorous, and the collector must beware of putting species he would keep alive into a box or fernery with such forms as *Selenites concava*. The latter will make short work of them, extending its slender body far into the whorls of its defenseless prey and eating them, all alive, voraciously. A single *Selenites* will clean out a dozen *Helices* of its own size in a single night. A Floridian bird of prey, the everglade kite (*Rostrhamus sociabilis*), is said to have a special fondness for *Ampullaria*, and the curve of its beak and the formation of its claws are specially adapted for preying upon them and extracting the body of the snail from behind its protecting operculum. Certain millipedes of the genus *Julus* are often found feasting upon slugs and snails, but whether they attack specimens in good health is not positively determined.

The treatment of specimens collected, including methods of cleaning and preservation of the soft parts, will be discussed later.

FRESH-WATER SPECIES.

The molluscan fauna of fresh waters includes both Gastropods and Pelecypods. All regions having permanent bodies of fresh water, whether lakes, ponds, rivers, brooks, or even springs, present a certain number of species, which, however, varies greatly with the more or less favorable nature of the environment.

HABITAT AND STATION.

As lime forms the chief component in shell, waters containing an abundant supply of this mineral are more favorable for the multiplication of shell-bearing animals than those which contain but little lime. As the development of molluscan embryos is more rapid and effective in warm than in cold water, a temperate or warm climate favors the multiplication of individuals. The character of the bottom influences the welfare of mollusks; a coarse crystalline gravel, more or less disturbed by a rapid current, is distinctly less adapted to them than softer and less gritty sands, mud, or even solid rock, over which the water flows more gently. The food supply is, of course, of great importance and the presence of algæ or other plants in abundance, by promoting the multiplication of the microscopic organisms upon which many mollusks feed, is indirectly advantageous to those species which may not feed on the plants themselves.

The presence of carbonic acid (carbon dioxide) released by the decay of vegetation and taken up by the water is not only unfavorable to molluscan life directly when present in quantity, but indirectly, by causing erosion of exposed parts of the shell and rendering necessary an exceptional secretion of shell substance to repair these damages, is weakening to the animals and very injurious to the shells, viewed as material for study.

The range of temperature borne by fresh-water mollusks is very great. Some species of *Pisidium*, *Sphærium*, and *Limnæa* are found at great altitudes (6,000–14,000 feet) in pools where the temperature seldom rises much above the melting snow from which they spring. On the other hand species of the same genera as well as *Planorbis* and gastropods belonging to the *Amnicolidæ* occur in the waters of thermal springs which have a high temperature. Most of the fresh-water mollusks appear to enjoy a certain amount of sunlight, or at least are not repelled by it, though as Dr. Lea has shown, some of the Naiades (and possibly all of them), though without organs of sight, are distinctly sensible to the influence of light. On the other hand a certain number of species, mostly of small size, frequent subterranean waters, deep wells, or the lower depths of great lakes.

The presence of impalpable mud suspended in the water is as obnoxious to gill-bearing mollusks as clouds of dust are to air-breathing animals, and for the same reason. Salts of borax, magnesia, soda, and potash are injurious, and, when abundant, are fatal to molluscan life, although when the change is brought about with extreme slowness some hardy species may survive in the presence of salt enough to render the water perceptibly brackish. The effect of the change is generally apparent in a tendency of the shells to become ribbed, dwarfed, abnormally thickened, or distorted under such conditions. Conversely, marine species, if the change be sufficiently gradual, may survive in water which has become nearly or quite fresh, and thus present the naturalist with such anomalies as the fresh-water arks, cockles, and teredos of India and the river limpets (*Acmæa*) of Borneo.

As lakes become saline the species which can not migrate die, but those capable of doing so are apt to retreat to the streams feeding such lakes, and finally to the springs which feed the streams. So that in the case of the Pleistocene Lake Bonneville, of which the Great Salt Lake of Utah is a remnant, the mollusks, long thought to be extinct, which lie fossil in myriads on the ancient shore lines, have one by one been discovered living in the few springs which remain in that arid region, until the discovery of *Tryonia*, in 1891, by Dr. Merriam, made the list complete. In mountain pools, wet meadows, ditches, and ponds are found the small bivalves of the genera *Pisidium* and *Sphærium;* in larger ponds, canals, and slow-moving waters *Anodonta* flourishes, while *Unio* and the larger Naiades seem to prefer streams, often lying in full view on a hard rocky bottom or slowly pushing themselves about on the mud or sand. Marshes give shelter to the operculate

Viviparidæ, *Ampullaria*, and *Hydrobiinæ;* in ponds and sluggish streams *Planorbis*, *Limnæa*, and *Amnicola* abound; estuaries afford *Corbicula*, *Cyrena*, and *Melanopsis*, beside such modified marine species as *Azara*, *Tagelus*, some *Rissoidæ*, *Neritina*, and *Bithinia*, and occasionally half marine *Cyrenoidea* and *Psammobiidæ*. Swift streams often teem with Melanians of different genera, and under their pebbles lurk fresh-water *Neritina*, *Planorbis*, and *Ancylus*. Lily pads are a good collecting ground for small specimens, and in the tufts of water-loving grasses as well as the soft mud about their roots numerous mollusks may be found.

OUTFIT.

For carrying the larger bivalves a bag or basket is convenient and a dip net with rather wide meshes will enable the collector to search soft mud for bivalves or pick up Naiades from water too deep for the arm alone. A few vials for the smaller species, a tin water pail for preserving interesting forms alive, a thin-bladed knife for roughly cleaning large bivalves, and the ever useful forceps will make an outfit quite sufficient for the collector's needs.

FAVORABLE LOCALITIES.

The preceding remarks will have indicated places where search may preferably be made. The drift along river and lake beaches and the vicinity of muskrat burrows will often afford dead specimens in good condition. Trailing weeds and the long fibrous roots of trees often conceal rarities in their meshes.

EGGS.

The eggs of fresh-water gastropods are often deposited in little masses of clear jelly, which may be preserved in fresh water and reared in an extemporized aquarium. Goldfish globes or thin jars of plain glass are quite as good and much cheaper for such purposes than the more pretentious metal-framed aquaria for sale by dealers.

ENEMIES AND PARASITES.

The muskrat and the wild duck feed largely on mollusks. In the crop of the latter and about the burrows of the former specimens still suitable for study may often be found. The embryos of fresh-water bivalves are often provided with temporary hooklets, by which they adhere to the fins of small fishes or the legs of other water animals, and are thus transported from one pool or stream to another. In the gill pouches of many species the young remain until their development is well advanced. This is especially the case in the *Unionidæ*, and the swelled organs in their season are often very remarkable and offer an inviting field for special study. The sexes are separate, and as the growth of the shell goes on during the gravid season its form in the female is often modified by the mechanical pressure of the soft parts, so

that the male and female differ widely in their shape. The external sculpture, of which so many species offer examples, is probably initiated in most instances by growth of the shell over the plicated network of the gills, another field open for much needed research. The very young shells often have characteristic sculpture, lost by erosion in the adult, and they should be carefully sought for and preserved. The young of the *Corbiculidæ* generally nestle in a sort of marsupium within the parent until of considerable size, affording a good opportunity for identification and for the study of the larval calyculate beaks found in various species.

The tropical forms of *Sphærium* show black maculations not found in northern forms, which on close examination will be found to be external to the shell on its inner surface. Their nature is still to be explained, and the naturalists of our southern border would do well to examine into the matter.

The parasites of fresh-water species are not numerous. They comprise rhizopods, infusoria, and cercarian worms, like the embryonic stages of the sheep and other flukes. These occur in *Limnæa* especially. Small mites are found on them also, and they may sometimes be seen on *Unio*. The beautiful pearls which occur occasionally in *Unio* and its allies are said to be frequently initiated by the irritation of a *Gregarina*, over which the tormented mollusk pours out a film of nacre to protect itself. Other pearls are due to the accidental intrusion of grains of sand or the hooked embryos before referred to. Pearl hunting is not part of the naturalist's work, though he may sometimes be rewarded by a "find." It has been calculated that one *Unio* in a hundred contains a pearl, that one pearl in five hundred has a commercial value, and about one in a thousand is worth more than $5. So it will be seen that pearl-hunting is not a profitable pursuit in the long run, and, by its involving the destruction of myriads of interesting animals in regard to which the naturalist has almost everything yet to learn, it is placed in the category of pursuits which those interested in biology may reasonably discourage.

Fresh-water collecting in the tropics does not differ essentially from the same pursuit in more temperate regions, except by the greater prevalence of paludal fevers in the haunts of the collector's prey.

In deep lakes interesting collections may sometimes be made by means of dredging, but as this does not differ in any essential way from marine dredging the reader is referred for details to the section of this paper relating to explorations of the sea.

In closing this part of our remarks we would emphasize the desirability of maintaining aquaria for the study of the habits of the living animals. Fresh-water aquaria may easily be made by anybody and require hardly any attention, while they afford an indispensable method of learning the ways, habits, and life history of fresh-water animals and offer an attractive ornament to the study or the parlor.

MARINE SPECIES.

As everyone is aware, the sea is the most prolific region for molluscan life, far exceeding in the number of its species the land and freshwater regions combined. A similar disproportion exists between the respective numbers of families and genera. The earliest known mollusks were coëval with the earliest fossiliferous rocks and were marine forms. Air-breathers are not known to have existed before the Carboniferous period, but when the much more ancient Cambrian forms were living the molluscan type was already old and exhibited development in several of its principal lines. There can be no doubt that the sea has continuously existed since the earliest development of life on the globe, and most naturalists believe that in it the first organic life took rise. Marine mollusks, regarded as a whole, have therefore formed a continuous series, and in the depths of the sea are to be sought those recesses where change of conditions from age to age has remained at its minimum. There linger forms which are of incalculable antiquity, some of which differ little, regarded as generic types, from some of those which existed in Paleozoic time; while representatives of genera developed in Cenozoic time are numerous.

REGIONAL DISTRIBUTION OF SPECIES.

The existing sea, with reference to its molluscan population, is divisible into two sorts of regions. One set is most easily defined as that of areas differing by differences of latitude, the other by differences in depth of water. These differences in either case are not absolute but relative, depending on temperature and food supply, but, in a general way, we are not inaccurate when we speak of Arctic, Boreal, Temperate, Subtropical, and Tropical mollusk-faunas, or those of the shores, the shallows, and the abysses.

The waters immediately adjacent to the shores were long ago divided by Forbes and other pioneers in marine exploration into zones or areas according to the conditions characterizing them; as, for instance, the Laminarian zone or region of brown kelp, the Coralline zone or region of stony algæ, etc. But for general purposes and to contrast the areas of the whole sea, one with another according to their chief characteristics, we may divide the entire sea bottom into three regions.

The first is that to which light can penetrate and therefore where marine vegetation can exist. This is the Litoral region, and in a general way, modified by especial conditions at particular places, it may be regarded as extending from the actual shore out to the limit of 100 fathoms. Beyond this it is practically certain that no light reaches the bottom of the sea and no sea weeds grow. Outside of this the borders of the continents slope gradually to the bottom of the ocean, which is found usually at a depth of about 2,500 fathoms.

On the upper parts of these continental slopes the conditions are often very favorable for marine life. Currents of comparatively warm water,

like the Gulf Steam, sweep along, bringing fresh, pure water and supplies of food to the animals along their track. The division between the abysses and the slopes is rather a matter of temperature than of mere depth. But the temperature itself is somewhat dependent on the depth, the influence of the great warm currents rarely extending below seven or eight hundred fathoms, and this depth corresponds roughly to a temperature of about 40° F. Below this it diminishes as the depth increases, at the rate of about one-tenth of a degree to 100 fathoms until the freezing point is reached, though there is no reason to suppose that the abyssal water ever actually becomes congealed.

To the cold, dark area of the ocean bottom has been applied the name of the Benthal or Abyssal region, while that between the Litoral and Abyssal areas has been designated as the Archibenthal region.

DEEP-SEA MOLLUSKS.

While the average collector may not hope to explore the recesses of the Abyssal and Archibenthal regions, a few observations on the relative conditions which obtain there will assist in the comprehension of the general subject of the life of marine mollusks, and may therefore be permitted.

Deep-sea mollusks, of course, did not originate in the depths. They are the descendants of those venturesome or unfortunate individuals who, by circumstances carried beyond their depth, managed to adapt themselves to their new surroundings, survive, and propagate. Many species must have been eliminated to begin with. Others more plastic, or more numerous in individuals, survived the shock and have gradually spread over great areas of the oceanic floor. In accordance with these not unreasonable assumptions, we should expect to find among the newer comers at least some characters which were assumed under the stress of the struggle for existence in the shallows, and which, through specific inertia, have not become wholly obsolete in the new environment. We should also expect to find a certain proportion of Archibenthal species in any given area, identical with or closely related to the analogous Litoral region forms of the adjacent shores.

In the Abyssal region alone should we expect to find that any considerable proportion of the fauna has lost all its litoral characteristics, assumed characters in keeping with its environment and become disseminated over the ocean bottom throughout a large part of its extent. These expectations in the main are fairly satisfied by the facts as far as the latter are positively ascertained.

In order that their existence may be maintained the abyssal mollusks require oxygen to ærate their circulation, food to eat, and a foothold upon which they may establish themselves. It is necessary that the conditions should be such as will not prevent the development of the eggs by which successive generations are propagated, and that they do permit it may be assumed from the very fact that mollusks in large num-

bers have been shown beyond all question to exist on the oceanic floor wherever this has been explored.

In general it seems as if we might safely assume that the composition of abyssal sea water shows no very important differences from that of other sea water, and that the animals existing in it are not exposed to any peculiar influences arising from this source alone.

This can not be said of the physical conditions. Everyone knows how oppressive to the bather is the weight of the sea water at only a few feet below the surface, and how difficult it is to dive, still more to remain on the bottom, if only for a few seconds.

But it is difficult to convey any adequate idea of the pressure at such a depth as 2,000 fathoms, or about 2 miles below the surface.

Rope made impervious by tarring is said to have become reduced one-third in its diameter by a descent into these depths. Any hollow object not pervious or elastic is at once crushed. There is no doubt that at some points on the ocean floor the pressure may amount to several tons to the square inch.

If we recall that the average pressure in steam boilers is probably much less than 100 pounds to the square inch it may help toward an appreciation of the abyssal conditions.

The inevitable conclusion is, therefore, that all the animals living under these conditions must have their tissues so constituted as to permit the free permeation of the water through every part in order that the pressure may be equalized. How this is possible without putting an end to all organic functions is perhaps the greatest mystery of abyssal life. How can a large egg, like those of various deep-sea animals, pass through the stages of segmentation and development, with every molecule of its structure in actual contact with ordinary sea water and every solid particle subjected to a pressure of say a thousand pounds to the square inch?

Such questions are much easier to ask than to answer, in fact no attempt at an answer has, so far as I am aware, ever been offered to biologists.

The looseness of tissue necessary to such a permeation is conspicuous in abyssal animals, whose flabby and gelatinous appearance when they reach the surface is notorious. It is perhaps most noticeable in the fishes, which nevertheless are often armed with formidable teeth. But under the great pressures of the deeps it is quite conceivable that each of these loose and half dissolving muscles may be compressed and reduced to a condition resembling steel wire; and that the organization thus sustained may be as lithe and sinewy in its native haunts as its shallow water relatives are in theirs.

The operculum is generally horny in abyssal mollusks, frequently disproportionately small, compared with that of congeneric litoral species, and in a remarkably large number of cases is absent altogether.

The genus most abundantly represented of all is *Mangilia*, which is

entirely without an operculum, and affords a conspicuous example of the obsolescence of protective devices, originally acquired in shallow water, resulting from long residence in the deeps.

In the Unio and Melania of fresh-water streams and the pond snails of our lakes and ponds, the waters of which from the decay of vegetable matter are overcharged with carbonic acid, we find a dense thin greenish epidermis developed as a protection against erosion. In the deep sea where every portion of the shell must be permeated by the surrounding element to equalize the external pressure, and where carbonic acid exercises its usual malign influence on the limy parts of all organisms, we find a strikingly similar protective epidermis developed in most unexpected places. Thus it comes about that in the *Trochi*, *Pleurotomidæ* and other characteristic abyssal animals we find those puzzling and remarkable counterparts of land and fresh-water shells which have astonished every student of the mollusca who has seen them.

The influence of darkness upon the inhabitants of the Abyssal Region has often been expatiated upon. The absence of visual organs or their preternaturally excessive development beyond the normal of the groups to which the individuals belong is evidence enough that the deeps are markedly darker than the shallows. But this evidence proves too much for the claim that the deeps are mathematically dark. Whatever notions may be entertained or conclusions deduced by the physicist from the premises, the presence of large and remarkably developed eyes in many abyssal animals shows that light of some sort exists even on the oceanic floor. It is inconceivable that these organs should be developed without any light and if the experiments and reasoning of the physicist result in the apparent demonstration of absolute darkness in the depths, the facts of nature show that in his premises or his experiments there lurks some vitiating error. It is ridiculous to suppose that the phosphorescence of certain animals in the deep-sea fauna is a factor of sufficient importance to bring about the development of enormous and exquisitely constructed eyes in a multitude of deep-sea species. A greater or general phosphorescence, such as would amount to a general illumination, has never been claimed by any scientific biologist and, as a theory, requires a mass of proof which seems unlikely to be forthcoming.

In general, then, we find the physical conditions simpler than those of the shallows, and yet much more energetic. The effect of temperature is marked in the distribution of life over cold and warmer areas of sea bottom. The relative importance of the effects of pressure, partial darkness, and of the quietness of abyssal waters, our knowledge is yet too imperfect to allow us to precisely estimate. All doubtless have their effect; some of the effects are more obvious than others, but it is by no means certain that the most obvious are necessarily the most important to the organisms concerned.

We are yet ignorant as to whether the abyssal and archibenthal faunæ shade gradually into one another, as seems most probable; or whether there is any line of depth, coincident with a temperature limit, which really fixes a boundary for the abyssal fauna.

To give the student some idea of the kind and distribution of life in the different benthal regions of the sea, two tables have been prepared which illustrate the peculiarities of the collection made during the past ten years on the southeastern shores of the United States and in the Antilles by the United States steamer *Blake* and recently reported on.

It is probable that it offers a fair example of abyssal mollusk faunas, but this can not be claimed with certainty.

The first table shows the general numerical results for the *Blake* collection, assorted among the great systematic groups and the three bathymetric zones or areas. The second table shows the proportion to the whole population of the abyssal region borne by those genera which exceed a single species. The result here shown is that less than 37 per cent of the genera comprise more than 68 per cent of the species; and out of these, three families, *Pleurotomidæ*, *Ledidæ*, *Dentaliidæ*, furnish nearly 28 per cent of the species of the abyssal fauna collected by the *Blake*.

TABLE I.—*General numerical results.*

Groups.	No. of genera.	No. of species.	Species in the—			Species common to—		Abyssal fauna.	
			Litoral area.	Archibenthal area.	Abyssal area.	Two areas.	All areas.	Families.	Genera.
Brachiopods	7	13	8	12	3	8	2	2	3
Pelecypods	52	170	98	114	31	64	10	15	19
Scaphopods	2	35	17	28	12	17	5	1	2
Gastropods	119	491	280	222	83	161	32	29	41
Total	180	709	403	376	129	250	49	47	65

TABLE II.—*Genera represented by more than one species in the abyssal area.*

Genera.	No. of species.	Genera.	No. of species.
Mangilia	17	Fluxina	2
Margarita	5	Liotia	2
Pleurotoma	4	Leptothyra	2
Drillia	3	Cocculina	2
Marginella	3		
Scala	3	Leda	5
Calliostoma	3	Limopsis	3
Triforis	3	Pecten	3
Actæon	3	Abra	2
Utriculus	2	Myonera	2
Fusus	2		
Columbella	2	Dentalium	8
Benthonella	2	Cadulus	4

Total, 24 genera and 87 species.

For the naturalist of to-day the most interesting feature of abyssal life is not that it furnishes him with singular and archaic forms, useful in his study of extinct genera; nor the beauty and rarity of the creatures living under such unusual conditions. The most important characteristic of abyssal life is, that it, and it alone, exhibits a fauna in which reciprocal struggle is nearly eliminated from the factors inducing variation and modification.

Hence the course of evolution and modification, though still complex, is certainly much less so than in the shallower parts of the ocean. For this reason we may hope to penetrate more deeply into its mysteries with deep-sea animals than with those less fortunately situated. In this opportunity lies the chief importance of research into the biology of deep-sea mollusks. Nowhere else may we hope to find the action and reaction of the contending forces less obscure, and modification in most cases has not extended so far that we can not compare the deep-sea forms with their shallow-water analogues and draw valuable conclusions.

For an account of the methods and apparatus employed in deep-sea researches the student may be referred to the following works:

Three cruises of the U. S. Coast and Geodetic Survey Steamer *Blake* in the Gulf of Mexico, etc., by Alexander Agassiz. Boston: Houghton, Mifflin & Co., 1888; 2 vols. 8°. With many maps and illustrations.

Deep Sea Sounding and Dredging (etc.), by Chas. D. Sigsbee, Lieut. Com. U. S. Navy. Washington: Coast and Geodetic Survey, 1880. 4°. With many illustrations and supplement dated 1882.

MOLLUSKS OF THE LITORAL REGION.

The litoral region may be divided into several subordinate areas, the first of which is the beach, or litoral proper, between the extreme range of the tide or high and low water mark. The next has been called the area of sea-weeds or laminarian zone from the *Laminaria*, or long-leaved kelp, which grows in it. Its extent varies in different parts of the world, but in general is regarded as between the low-water mark of spring tides and a depth of about 15 fathoms or 90 feet of water.

Outside of the laminarian zone and extending to the limits of the penetration of light into the depths is the coralline zone, where the vegetation consists chiefly of stony algæ, or nullipores, and in which *Polyzoa* or corallines are most abundant. The outer limit of this zone is usually taken as 100 fathoms (600 feet), an arbitrary limit, but approximating to the truth.

Most collectors find their chief resource in the beach, where they obtain not only the mollusks proper to that region but many others cast up by the sea which normally inhabit the outer zones.

Those fortunate enough to secure the use of a rowboat and dredge, find a rich field accessible to them in the laminarian zone and the inner

margin of the coralline zone. For work in the deeper parts of the latter a sailboat or small tug and a crew of several men are necessary for effective work, but the trouble and expense are well repaid by the rarities which can be secured in this and no other way.

The mollusks of the beach differ widely in different latitudes. In the north *Litorina*, *Purpura*, and various limpets frequent the rocky and stony shores, while near low water on the under surface of flat stones and under overhanging ledges several species of *Chiton* find a congenial home. Among the barnacles and under the profuse fronds of the bladder weed small Rissoids and the urnlike ovicapsules of Purpura are common. On the Californian coast *Haliotis*, *Acmæa*, and many Chitons abound in such localities. As we go south the fauna of stony beaches becomes richer, and a vast number of small shell-bearing and naked mollusks inhabit them. Where there is a mixture of stones and sand, large sea-anemones or *Actinia* live between the pebbles, often covered with fragments of shell and bits of gravel, amongst which careful examination often reveals many small shells sticking to the adhesive surface of the polyps. These must be secured by means of the forceps, as they are not easily detached.

On the sandy beaches will be found a special fauna, without taking into account the species thrown up by the waves from deeper water. *Natica* is one of the most common gastropods, and living specimens may readily be detected by the little mound of sand which they push before them as they plow their way just below the surface. *Nassa* is one of the most familiar forms in such places and, like *Natica*, is predacious, living on the flesh and juices of bivalves, which it seeks beneath the sand, drilling in their shells the small circular holes which may be noticed in the majority of the dead bivalves strewn upon the beach. In the south *Fulgur* is one of the largest and most common of the gastropods characteristic of the sand beaches, and its horny coils of ovicapsules, in the shape of angular spiny disks adhering by one edge to a connecting lamina, are among the most frequent objects on the shore. The drills, *Urosalpinx* and *Eupleura*, so destructive to young oysters, abound in many places. The bivalves exceed all others in the number of individuals. *Mactra*, *Petricola*, and *Macoma* in the north, with *Donax*, *Tellina*, *Venus*, and *Dosinia* in the south, are among the most conspicuous forms. Living specimens are usually concealed under the surface. Small holes in the sand, by which water obtains access to their siphons, indicate the spot they occupy. Advancing waves will often uncover thousands of small specimens of *Donax*, which disappear as if by magic as the water recoils. *Olivella* and *Oliva* frequent sand beaches near low-water mark and also are burrowers. In Florida *Strombus pugilis*, *Melongena corona*, and *Pyrula papyratia* are very abundant in such places.

On muddy flats, especially if somewhat sprinkled with gravel or pebbles, another set of mollusks may be found. *Mya* and *Petricola*, certain

species of *Macoma*, and the mud-loving *Ilyanassa* are invariable members of the fauna and wherever a sprinkling of wiry salt-water grasses checks the motion of the water there one finds hosts of *Astyris*, *Cerithiopsis*, *Triforis*, *Bittium* and small species of *Odostomia* and *Mangilia*. A little further seaward where the water rarely leaves them are the oysters, with their attendant *Anomia*, *Crepidula* and little gastropods, not to mention the drills and other enemies varying with the latitude. In the narrow ditches commonly cut in New England for the quicker drainage of salt marshes as the tide recedes, *Littorinella* is often abundant with *Bittium* upon the vegetation. In half submerged beds of peat *Petricola* and *Zirphæa* live in borings which they enlarge as they grow, while the piles of old jetties or the softened wood of wrecks when split open usually reveal the borings of *Teredo*, *Xylotrya*, and *Martesia*, often containing the author of the damage. The canals of sponges, of the brittle sort known as "bread sponges," often contain small gastropods which take refuge there; and such sponges are common on the oyster beds and in the pools on stony beaches just below low-water mark, especially on our southern and southeastern shores. The crannies of old weed-grown seawalls are a good collecting ground and in such places and on floats and old piling some minute species usually occur which may be vainly sought elsewhere.

In tropical regions the coral reefs, whose tops are usually accessible at low water, have a rich and varied fauna of their own. The stems and aerial roots of the mangrove are favorite haunts of *Litorinidæ*, tree-oysters, *Cerithidea*, and the like, many of which remain for hours out of the water. In the mud at their base *Arca*, *Saxicava* and many others are almost inextricably mixed with the tubes of *Vermetus*, *Petaloconchus*, and various worms. When the roots extend into clear water they are a favorite haunt of the salt-water species of *Neritina* and of *Nerita*. Under the overhang of rocks and the sides of bowlders which stand between tide marks the amphibious *Siphonaria* and *Gadinia* may be found associated with chitons and true limpets. Among the pebbles at low-water mark may be found hosts of *Turbinidæ*, like *Uranilla* and *Pachypoma*, *Trochidæ*, like *Chlorostoma* and *Liotia*, the slipper limpets, the cup and saucer limpets (*Crucibulum*), *Capulus*, and *Amalthea*. In gravelly places occur myriads of *Cerithium* and *Columbella*; while the cones prefer muddy places, the bivalves the sandy beaches, and the murices the rocks and oyster beds. The catalogue might be almost indefinitely prolonged, but the above hints will be sufficient to start any intelligent collector on the right track, when after a little experience he will not need more detailed suggestions.

OUTFIT.

For ordinary beach collecting the collector, beside pill boxes and vials for frail or minute specimens, and a supply of alcohol in one or two wide-mouthed bottles or screw-topped jars, will find a basket or bag

convenient for the larger species; a knapsack of painted canvas being best, as fluids do not leak out of it. A hammer, or small pick and hammer combined, is frequently useful to crack rocks or coral for pholads, or rake the gravel for hidden gastropods. To dig out living bivalves a spade and a good deal of energy are required; such collecting is best made the subject of a special excursion. On the Pacific coast a small rod of three-eighths inch iron, hammered to a chisel-shape at one end and to a point at the other, is very useful in detaching *Haliotis*, or large chitons, from the rock. If the blow is sharp and unexpected the mollusk will usually fall without injury, and in many places a small dip net will be of use for securing it. But if the mollusk is irritated or disturbed before the collector strikes in earnest, it is better to pass on, for the creatures when aroused will hardly be detached without injury, so effective is their hold on the rock. The same is true to a minor degree of the limpets. If chitons are collected they should be placed on a narrow strip of smooth wood like a ruler, well wetted with salt water, before they have time to curl up. By putting them opposite one another and tightly winding soft twine, list, or lamp-wicking around both chitons and stick, they will be kept in a normal posture until the tissues are relaxed and they can then be preserved in spirits or cleaned. If this precaution is not taken they are apt to curl up in a shape which renders them almost useless for dissection or for cabinet specimens and they will break rather than flatten out. A large number may be set on a single stick. If, however, they curl before they can be set, it is best to put them in a pan of salt water when they will, if alive, eventually resume a normal position. A small sieve, with meshes of one-sixteenth of an inch, is often useful for sifting the sand out of drift material which collects at high water and along the ripple marks. This can be put in a bag or bottle and picked over at home. It is often very rich in small species. An old table knife is useful for detaching limpets or chitons from smooth rocks. The dip net, if the frame is solid and the meshes small, may be used to dredge out small bivalves from the loose sand near low-water mark or from the soft mud of marshy shores.

FAVORABLE LOCALITIES FOR SHORE COLLECTING.

In the preceding remarks a statement of the special habitat preferred by special groups has been embodied, and as conditions vary in different regions, the collector will find experience the best teacher in seeking favorable spots for his work. It may be said, however, that the richest fauna is likely to occur where a combination of varied elements constitutes the shore. A beach composed of a mixture of mud, sand, and gravel, or of mud and sand diversified by projecting rocks is always more fruitful in species than a stretch of exclusively sandy, rocky, or muddy shore. This is partly because of the varied conditions which suit a larger variety of mollusks, and partly because the same diversity of bottom promotes the multiplication of the organisms which serve the mollusks for food.

Again, as a reasonable degree of motion in the water brings to sedentary animals a larger supply of food than would otherwise be within their reach, we usually find points and headlands, or islets, washed by marine currents far richer in species than those beaches subject only to the ordinary ebb and flow of the tide.

Places where fishermen draw their seines are apt to afford specimens accidentally brought in from deeper water. The haddock and some other fishes live partly on mollusks, and therefore the bits of beach where fish are cleaned often repay a search, in spite of incidental annoyances common to such places.

The late Dr. A. A. Gould had a regular understanding with certain fishmongers that they were to empty the paunches of their haddock into a bucket of clean water, which was afterward strained off, the debris affording many rarities which could be obtained in no other way. The crops of sea ducks are often crammed with small bivalves, such as *Nucula* and *Leda*. Among other facilities for collecting which the markets of a large city afford, apart from the supply of edible species brought for sale, may be mentioned the mud which remains in the barrels in which oysters are brought to market. This will often afford a great many small species if washed and sifted.

Among other out-of-the-way places where rare and singular mollusks may be obtained are the burrows of crustaceans which are frequently inhabited by species of *Lepton*. This genus appears to be frequently commensal in its habits. Around the mouth and in the channels which radiate from that aperture, in such Echini as *Hemiaster*, a small commensal species of *Lepton* is frequently found. A burrowing crustacean (*Gebia pugettensis* Dana), living on Puget Sound and the coast of British Columbia, frequently carries under its abdomen a species of *Lepton*, attached to the crab by its byssus, as a lady carries a chatelaine bag at her belt. The margin of the shell is curved to fit the rotundity of its host, and the mollusk has not been found alive in any other situation. A minute hyaline gastropod (*Stilifer*) is an habitual parasite of starfishes, living half imbedded in the tissues, from which it sucks the juices. Another gastropod (*Thyca*) is more strictly commensal, and establishes itself near the anal opening of its echinoid host, from whose ejecta it is supposed to obtain sustenance. Very similar species belonging to the same family were semiparasitic on many paleozoic crinoids, growing as their host grew, remaining permanently in the same spot, and frequently inducing distortion in the echinoid thus ridden. A still more extraordinary case is that of *Entoconcha mirabilis*, a degraded mollusk which is an internal parasite of *Synapta*, a worm-like organism found on sand beaches. The *Entoconcha* is found as a sac-shaped mass in the intestine of the *Synapta*, only recognizable as a mollusk by the development of its eggs, which pass through the usual molluscan stages, while the larval animal possesses a small shell, afterward lost, as in the case of many Tectibranchs. The small gastropods

which haunt the canals of *Cliona* and other "bread sponges" are probably commensals rather than true parasites, and find shelter in these passages while their food is conveniently brought to them by the ciliary currents kept up by the sponge.

Small mollusks may often be found in the stomachs of starfish as well as other marine animals. In the Arctic regions the walrus, after using his great tusks to rake *Astarte* and *Natica* out of their muddy bed, is in the habit of swallowing them whole. The shells, frequently little injured by their journey through the animal, may be found in large quantities on the rocky beaches where the walrus "haul up" on the shore. The roots of kelp and the branches of sea fans and other corals are the peculiar habitat of a few interesting and often very rare forms.

EGGS AND EGG CASES.

The eggs of bivalve mollusks are usually protected within the valves of the mother, and when the sexes are separate, as in a majority of bivalves, this habit results in the modification of the form of the female shell. In some species the larval mollusks cling to the gills of the parent, in others there are special pouches modified for their use, and these differences occur in most closely related species of one genus. In other groups, as in the cases of *Perna*, *Cardium*, *Poromya*, and *Cuspidaria*, the gills may be so attached to one another and to the mantle, or the siphonal septum may be so produced forward as to form a special chamber serving as a *marsupium* for the protection of the young. In gastropods the whelks deposit their eggs in horny or leathery ovicapsules generally anchored to some stationary body. The prickly coils of the egg cases of *Fulgur* have been already referred to. *Buccinum* deposits its capsules in a heap like grains of corn but so arranged as to admit the sea water to every part. They are commonly placed on or in some dead bivalve. The ovicapsules of *Purpura* stand on end, like little vases in groups upon the rock, usually under the bladder weed. *Chrysodomus* heaps its capsules in a cylindrical tower sometimes six inches high. *Voluta* and *Strombella* have a few large eggs in hemispherical or lenticular capsules an inch across. One species has a large, floating, spherical capsule. There are many gastropods whose eggs are not protected in this way. The nudibranchs lay theirs in a jelly-like mass, string, or coiled ribbon among the marine vegetation. The *Calyptraeidæ* protect their small yellow ova in a jelly-like mass between the muzzle and the front of the foot under the parent shell. At such times a strip or fringe of thin tissue, which runs along each side of the neck, becomes greatly enlarged and is wrapped about the egg mass as a mother would wrap her infant in a blanket. Of the eggs of a great majority of marine mollusks nothing is known, and here there is a most interesting field for study and observation.

ENEMIES AND PARASITES.

Sea mollusks are the prey of marine animals in general, and feed to some extent upon each other. There are no special or peculiar enemies except the boring sponge (*Cliona*), which riddles shells and other limy bodies with a network of small canals and chains of perforations familiar to every collector. Some *Polyzoa* erode the surface of shells to which they are attached and when removed leave marks resembling the pits on a thimble, often regularly arranged and sometimes taken for a normal sculpture by the unwary or inexperienced student.

COMMENSAL ORGANISMS.

Various worms and crustacea are commensal with mollusks, of which the oyster crab (*Pinnotheres*) is a most conspicuous and familiar instance. The shells infested by commensal worms are sometimes abnormally modified by their presence. On the other hand, a curious little mollusk (*Cochliolepis*) has been described by Stimpson, which lives only under the scales of an enormous annelid (*Acoëtes lupinus*) common in the harbor of Charleston, S. C.

The collector whose tastes and opportunities lead him to study the habits of life of mollusks can hardly fail, if patient and accurate, to add greatly to our knowledge. The literature of molluscan biography, if it may be termed so, is meager to an extraordinary degree. No better field for research can be imagined, and with experience it is found that the (apparently) most trifling details may have an important bearing and value.

DREDGING.

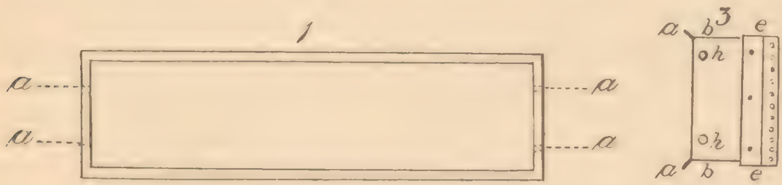
THE CONSTRUCTION AND USE OF THE DREDGE.

The dredge has been in use among naturalists since the last century. The form commonly in use for many years was that invented by Otho Frederick Müller, a Danish naturalist, and it is this form which is described in most of the text-books on conchology.* This instrument was composed of a rectangular frame of iron, with two movable arms extending forward, and with two large pieces of rawhide attached by wires to the hinder edges of the rectangle. The sides of these two pieces of rawhide were caught together with wire or twine in such a way as to make a net. This form of dredge is very inconvenient because, when not in service, the hide shrinks, dries, and becomes very hard, requiring to be soaked a long time in order to be fit for use: it is also difficult to turn such a net inside out in order to get at the contents of the dredge.

The modern dredge has been improved by Stimpson, and by the author of this paper. It consists, like the other, of a rectangular frame (Fig. 1), the sides being shorter than the upper and lower portions of the

* See Woodward's Manual, edition of 1871, p. 141, figs. 33, 34.

rectangle. The lower and upper edges in front are hammered so as to flare a little, like the edge of a chisel, (*a*, *g*, Fig. 2) thus plowing up the bottom over which the dredge is pulled. The edges of the short vertical sides are left without this bevel. In each side are two holes, (*h*, *h*, Fig. 3) in which are inserted the Y-shaped ends of the arm (Fig. 5) of each side, made of a slender (about three-eighths of an inch) iron rod. The anterior part of each arm ends in a ring formed by turning the end of the rod round. Parallel with and near to the back edges of the frame is punched a row of holes, as many as may be convenient. By means



FIGS. 1 and 3.—Dredge frame.

of rivets through these holes a thin strip of galvanized iron is attached, extending, on the outside, entirely around the back edge of the rectangle. The hinder edge of the galvanized iron extends about an inch behind the hinder edge of the frame. This is perforated with a row of small holes about an inch apart, extending entirely around the edge. To these holes a net (*d*, Fig. 2) and two flaps of stout canvas (*c*, *c*, Fig. 2) are laced with copper or galvanized iron wire. The object of the strip of galvanized iron is to hold the net away from the iron frame, which always rusts. This rust would very soon destroy the net, but if the latter is separated from the iron by the galvanized strip which does not rust, a single net may sometimes be used for a whole season, without need of repair. The

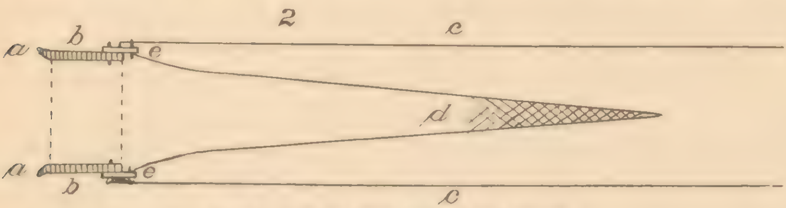
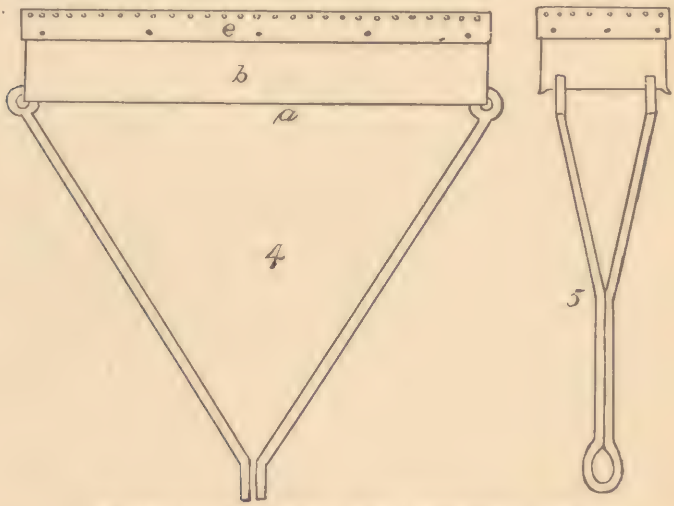


FIG. 2.—Dredge frame with net and canvas.

edge of the net to be laced on is placed inside of the galvanized iron. The front edges of the two strips of canvas are placed outside. These strips of canvas should be a little wider and about a foot longer than the net when it is wet and stretched. The lacing is done by sharpening the ends of a piece of copper wire or well galvanized wire, making holes in the canvas with an awl and passing the wire in and out as if sewing, so that the edges of the canvas, of the net, and the thin strip of galvanized iron are closely and carefully fastened together. The object of the strips of canvas is to receive the friction of the bottom, thereby preventing undue wear upon the net. As in sinking the dredge they are very apt to curl

over and get into the mouth of it, it is usually best to tie the lateral edges of the upper and lower flaps to each other, in one or two places with stout twine, which holds them in their place. The net itself can be turned inside out, and the dredge emptied without disturbing the flaps.

To have a dredge constructed, one should go to a blacksmith and not to a machine shop. The size of the rectangle forming the frame will differ according to the necessities of the case. If the dredge is to be used in a small boat in shallow water, it may be smaller and lighter than if it is to be used in a larger vessel, a sail-boat or by the aid of steam. The average dredge, for moderate depths of water to be used in a row boat, should be made of half-inch bar iron. The bar should be about three inches in width, and its length should correspond to the total circumference of the rectangle to be made, with a small allowance



FIGS. 4 and 5.—Dredge frame, showing arrangement of arms.

for welding. The holes for the rivets are to be made and the beveling of the upper and lower edges is to be done by the smith before he bends his bar into a rectangle. After the rivet-holes have been punched, and the edge properly fashioned, two half-inch holes should be made in that portion of the bar intended to form the vertical sides of the frame. These holes are intended for the arms. After all the holes have been punched, the bar may then be bent into the proposed rectangle and the ends welded solidly together. A convenient form is 20 inches from side to side, and 5 inches in height. The arms should be made of nail-rod and inserted in the holes which have been made for them, but the circle which the ends describe through these holes, inclosing the front edge of the frame, should be sufficiently large to allow the arms complete freedom of motion. The form of the arms will be seen from the figure. When in use they should form with the frame an equilateral triangle.

The ring at the front end of each arm should be bent vertically so that when the two arms are brought together in front of the dredge the two rings will be exactly opposite, and lie flat against each other. For the galvanized iron a strip about 2 inches in width is sufficient. This also should have the holes for the lacing punched into it and filed smooth before it is riveted to the frame, as it is much more difficult to do it afterward.

Suitable nets made expressly for dredges can be obtained from the Gloucester Net and Twine Company, Boston, Mass., or from any other manufacturers of nets. The net when dry is usually about 2 feet long; the meshes of the front part of it about half an inch in diameter. The bottom of the bag has smaller meshes, and is usually made double, or with double twines. Various sizes can be had to fit the dredge by mentioning the size of the frame in the order.

In deep-sea dredges, used by steam, it has sometimes been found that when the dredge first reached the bottom it cut so deep into the soft mud as to fill itself full at once, thereby preventing anything else from getting in. This difficulty was remedied by fitting a pair of wooden runners to the sides of the dredge, which would not allow the edge of the dredge to cut into the bottom until it had assumed a horizontal position. In ordinary dredging no precaution of this sort is necessary, since the dredger after a little experience will learn to regulate the length of the line and the position of the dredge for himself.

In attaching the dredge to the line it is usual to have a short piece of rope permanently attached to the frame. This rope may be 10 or 15 feet long. The front end is spliced to form a loop about 6 inches long. Into this loop the long dredge-line can be knotted when it is needed for use. The other end of the short rope is passed through one of the rings at the front end of one of the arms, then along the arm to one of the rings by which the arm is attached to the frame. Here the line is solidly fastened. When in use, the front ring of the other arm is attached to the opposite ring, through which the short rope passes, by means of a piece of ordinary twine, and it will be observed that the rope in no case should pass through both the front rings of the two arms. This is because it frequently happens that a dredge on the bottom may catch upon a bowlder or on other obstructions too heavy to be moved. If the rope passed through both arms of the dredge, the latter could not be raised, and therefore, with the line attached to it, would be lost. But when one of the rings only is tied with twine, by pulling hard upon the line the twine may be broken, and the two arms of the dredge will pull out straight and the latter may be recovered without damage.

In order to prevent the dredge from being raised above the surface of the bottom at its front edge by the inclination of the line to which it is attached, it is usual to attach a weight to the line some distance in front of the dredge, which makes the part of the rope behind that weight assume a more horizontal position. A convenient weight for this purpose

is a heavy sash-weight (A, Fig. 6) such as is used for windows by builders. The size to be used will depend upon the depth of water in which work is to be done, but a 10-pound weight is sufficient for ordinary purposes. It will be found convenient to roll the weight up in a strip of old canvas, and have it sewed securely, leaving some of the canvas in front and behind the two ends of the weight. This can then be sewed securely to the line with stout twine and will not require to be taken off. The author has found that in depths not exceeding 20 fathoms it was sufficient to attach the weight to the short line fixed to the dredge, just behind the point where the short line is attached to the long dredge line. For greater depths of water it should be placed further in advance, and in deep-sea dredging at a considerable distance, owing to the great length of the line used. For the latter work a weight of 50 to 100 pounds is sometimes needed.

ON THE USE OF A DREDGE IN A ROW BOAT.

Unless the dredge is very light and the water shallow, it is better to have two hands to pull the boat. The boat should be stout and steady,

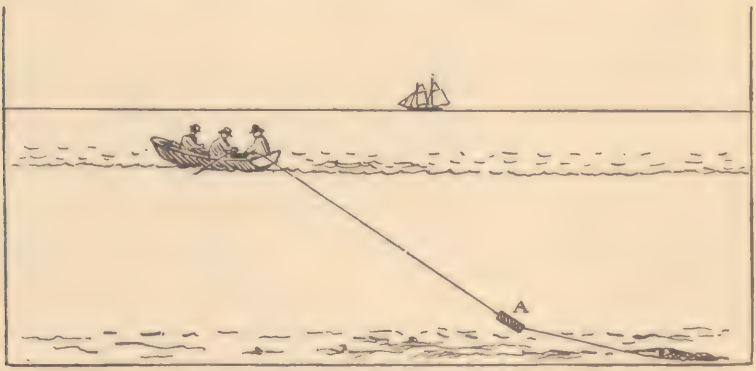


FIG. 6.—Method of using the dredge.

sufficiently large to hold its own well in the water and sufficiently heavy to avoid being anchored by the dredge when it touches the bottom. For most purposes one of those heavy boats used on sailing vessels, known as a ship's dingey, is perhaps the most suitable. The ordinary small light row boat, used for pleasure, is ill-suited for dredging purposes. There should be at the back end of the boat a sufficiently solid seat for the dredger to brace his feet against while standing up in charge of the dredge rope. It is advisable also to have room enough between the stroke oar and the dredger to set a tub for the purpose of holding the dredgings. It will also be found more convenient for each man, if two are employed, to pull a single oar rather than two. On getting to the dredging grounds, the dredger, after making sure that his line is clear, free from knots and twists, and securely fastened to the dredge, that the net in the dredge is not turned inside out, but

is in its proper position, and that the canvas strips are straightened out behind the frame, can proceed to do his work. The dredge should be put over the stern, the rudder having been unshipped, and allowed to sink gradually, the line being paid out quickly enough to allow the frame to sink faster than the canvas attached to it. In this way fouling will be avoided. The boat is better stationary while the dredge is being dropped. The long line used for the dredge is best of good soft manila rope, about three quarters of an inch in diameter. It should be coiled two or three times before being used, to take out kinks. Although a smaller line will do for shallow water, it is less convenient to handle. If the depth is considerable and the dredger supplied with only a moderate amount of line, it is perhaps best to fasten the inner end of the long line to one of the thwarts to avoid its being jerked overboard by accident. When the dredge is felt to touch the bottom, the men can begin pulling slowly. The dredger will pay out line enough in shallow water to the amount of at least twice the depth; in deeper water three times the depth may be needed. After some experience the dredger will find that no absolute rule in this matter can be laid down; that he will need a shorter line on muddy bottom than on hard bottom, in shallow water than in deep water, and that he may find it convenient, from time to time, to alter the amount of line paid out to meet the circumstances of the case. After the necessary line has been paid out the dredger will allow it to pass over the stern of the boat in the notch cut for the sculling oar, since, if the line is not amidships, it will be impossible for the men pulling the boat to pull straight forward. A turn may be taken around a cleat with the line, but the dredger should take hold of the line outside of the cleat with his hand, and continue to hold it. He will soon be able to recognize by the feeling of the line whether the dredge is passing over smooth bottom or rough bottom, whether it is biting into the bottom or not, and so on. If, after starting, the line remains quiet in the hand without transmitting any quivering motions, the dredge is probably not on the bottom, and more line requires to be paid out; or, if it is on the bottom, it is possible that it may have become fouled so that nothing is getting into it. When it is doing its duty, the dredger can not fail to perceive the peculiar sensations which are transmitted along the line. If the dredge catches on anything which holds it, one or two quick jerks on the line will probably release it. The length of time that the dredge should be towed varies with the conditions. On gravelly bottom, mixed with mud, a comparatively short time will be necessary to fill the dredge, when it may be hauled in. On sandy bottom, if it be not rich with life, the dredge may be hauled for a long time before it accumulates any considerable amount of material. All these things can be only briefly referred to here, since they are much better learned by experience. When the dredger thinks the time has come for hauling in, the rowers cease pulling, and he hauls in the line until the dredge is on the top of the water; but before taking

it over the edge of the boat, it is usually well to look into the mouth of the dredge to see if any very delicate specimens are there. When the dredge is emptied these would naturally be under everything else, and it would be better to take them out, if present, before emptying the dredge. The dredge can be emptied directly into the tub in the boat if it contains material which needs to be carefully examined. If, on the other hand, the contents are chiefly mud, it will be convenient to move it up and down in the water outside of the boat, and thus wash away a portion at least of the mud before taking it in. The dredger should take a note of the depth of the water in which the haul was made, which must necessarily be averaged; of the kind of bottom—muddy, sandy, gravelly, or weedy—and of the date. The writer has found it convenient to go out supplied with a number of nested wooden tubs, such as are sold for household purposes. The contents of the dredge after each haul can be put into a tub by itself. After all of the tubs are filled, it will be well to examine the contents in order to avoid carrying around useless material. If the dredger is near shore the most convenient way is to pull to the beach, provided there is no surf. Being provided with a wire sieve, of about a quarter-inch mesh, mud and fine gravel can be screened and the contents placed in jars, tin pails, or other receptacles, with the memorandum of the haul, so that no mistakes shall afterward be made in regard to the locality.

The proper method of using the sieve is to fill one of the tubs with water, then place some of the mud upon the sieve, which should be about one-half submerged, so that water will enter it to about one-half the height of the rim of the sieve, yet not so deep that the contents of the sieve can be washed over the rim. By using a rotary motion it will soon be found very easy to wash a considerable quantity of mud in a short time. In washing, the dredger will observe whether there are small shells or other objects so small as to go through the meshes. In case he finds this to be so, after he has washed out a certain quantity of mud, he can pour off gently the muddy water in the tub, and replace it by clean water, and by doing this repeatedly before the mud has time to settle he will find the small shells tolerably clean at the bottom of the tub. If foraminifera or other microscopic objects are desired, it will be necessary to preserve some of the mud, either in a wet or dry condition, for examination at home. If the contents of the dredge are not muddy, much less trouble is necessary in handling them. The richest bottom is usually gravelly, and this can be washed in the dredge itself before it is taken into the boat. Usually it will pay the dredger to take his tub of gravel home and examine it at leisure, since the necessary care can rarely be given in the midst of the operations of dredging. If, as sometimes happens, the dredge comes up nearly filled with pieces of kelp, or rolls of seaweed, these should not be hastily thrown overboard, since many animals live in and upon the fronds of weeds, and a careful examination will almost always repay the dredger

very well. When the dredge is emptied, the net should be turned inside out before it is returned to the bottom, and thoroughly washed, so that animals obtained at one haul shall not accidentally become mixed with those of the next.

THE USE OF THE DREDGE WITH A SAILBOAT.

In dredging from a sailboat deeper water can be reached than is convenient with a row boat. A person unaccustomed to the use of a sailboat will find it necessary to obtain the services of some one who is, since the management of a boat of this kind hampered by the weight of a dredge and line is no easy matter. If supplied with a competent sailing-master the method of work will differ little from that used in a row boat, except that the direction in which dredging can be done will be limited by the direction of the wind, and, by way of compensation, a much larger space of bottom can be dredged over in the same time.

Use of the trawl net.—In collecting with a sailboat it will often be found advantageous to make use of a trawl. The ordinary trawl consists of an iron frame somewhat like the two runners of a sled, fastened to each other by a heavy bar of iron, to which a large net is attached. The lower edge of the net in front is weighted with oblong leaden sinkers, so as to drag upon the bottom. A trawl of this kind is much used by fishermen, and sometimes in obtaining oysters. Such a trawl, though the coarseness of the meshes renders it unfit to collect minute material, will nevertheless frequently bring up dead shells, stones, and other objects of larger size covered with sessile animal life, together with large-sized mollusks, and in this way specimens may be obtained which it would be difficult to obtain by means of a small dredge. The improved trawl used in deep-sea dredging will be found described in works on deep-sea dredging, to which reference has already been made. In case the collector has an opportunity to accompany a fishing vessel on a trawling expedition he may obtain interesting forms which are brought up with the fish and other commercial products of the sea.

The trawl line.—Line fishermen use the word *trawl* in another sense, applying it to a line buoyed at each end, to which baited hooks are attached at short intervals, and which is set for fish. On this sort of a trawl, or, more properly, trawl line, large carnivorous mollusks frequently attack the bait, and when the fisherman examines his line, are often found sticking to it. A species which can not be dredged, owing to the irregular and rocky character of the bottom, may sometimes be obtained by making arrangements with fishermen to save the shellfish which they find attached to their trawls.

The baited net.—Another mode of collecting, which is available for persons having the use of a boat, over bottom which does not admit the use of the dredge or trawl net on account of its irregularity, is by means of a net such as is ordinarily termed a crab net by fishermen. Such a net is circular and attached to a large wooden hoop from 6 to

10 feet in diameter, according to the size of the net, and stretched with very little slack, so that when the hoop is held horizontally the net will not fall below it more than a foot or two at most. This hoop is attached by four cords, fastened to it and meeting over the center of the net at a distance of 6 or 8 feet from the hoop, to a line of sufficient length to reach the bottom, which is supplied with a small buoy at the surface. In the center of the net a bait is tied, preferably of dead and even partially decayed fish or flesh, since the carnivorous mollusks are apt to be attracted by the odor of any decaying animal matter. The net can be put down and left a convenient length of time and then hauled up. This should be done very carefully, so that the net will keep as nearly as possible in a horizontal position, and if any mollusks have crawled upon it to get at the bait they will be found in the slack of the net when it reaches the surface. If the net is hauled up incautiously, so as to turn it over or tip it sidewise to an inconvenient angle, of course the collector is likely to lose whatever may be upon it. In the writer's experience the most productive time for the use of such nets is at night, and it will be often found advisable to put the net down in the evening and raise it early in the following morning, when the results will be usually found more satisfactory than if the net has been merely allowed to remain on the bottom during the hours of daylight. In northern waters the collector is sometimes disappointed by the voracity of isopod crustacea, which appear in such swarms as to devour the bait in short order.

STEAM DREDGING.

If the collector lives near one of the larger cities, where small tugboats can be had for moderate hire and good dredging grounds are not too far off, it will be found profitable to obtain the use of a tug on some convenient occasion, since dredging by steam is far more effective, more rapid, and more easy than by any other method. The handling of the dredge is practically the same whatever power be used to drag it, but the use of a tugboat reduces the inconveniences to a minimum and enables the collector to go over more ground in the same time than can be covered by any other method. A search for suitable dredging grounds will require some experience and time. Usually grounds found available for ordinary line-fishing, if the water is not too deep, will be profitable for dredging, unless the bottom be very rocky and irregular. Inquiry of fishermen and watermen will often save a collector time and trouble, for such men are familiar with the grounds over which they are accustomed to fish and can designate the particular kind of bottom from long experience.

OUTFIT.

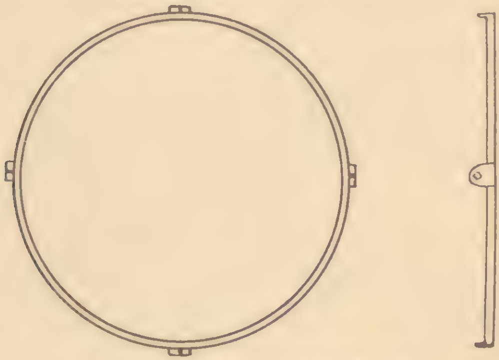
Besides the coarse sieve already mentioned the collector may, if he likes, provide himself with a finer sieve for sifting fine sand and mud

which has already been passed through the coarse sieve, but in practice the writer has not found this necessary. Most of the text-books direct a collector to have two sieves, one fitting into the other, the one coarser and the other finer; but, in the opinion of the writer, this is not only unnecessary, but objectionable. After trying sieves fitted in this manner he has had no satisfactory results. The motion of the sieve and the friction necessary to pass material through it are injurious to delicate specimens and should be reduced to a minimum. If the material being sifted is shaken and riddled through two sieves at once, without reference to its character, nothing of a delicate nature is likely to survive the process, and it is always better before sifting any of the material to look it over to some extent and to pick out such specimens as may be noted in order to save the injury to which they are liable if they are put into the sieve. Delicate objects, like naked mollusks, would be ruined by being sifted; in fact, if possible, they should be taken out of the dredge or landing-net and put immediately into separate cups of salt water until the collector is ready to prepare them for preservation. Similar care may be needed for other delicate objects, and for this purpose it may be convenient for the collector to provide himself with an ordinary box, like a candle box, to which the lid has been attached with leather or other hinges, and around the sides of which, inside, a strip or two of leather has been nailed, leaving loops large enough to fit a number of wide-mouthed glass bottles. These bottles may be filled with sea water and will serve to preserve temporarily the objects which the collector may desire to protect from injury or to study in a living state. A more troublesome, but perhaps more elegant, manner of reaching the same end is to have a thin drawer or shelf fitting the inside of the box and supported by a ledge on either end at a proper height, in which shelf circular holes have been cut fitting the jars or bottles used for this purpose. A landing net, such as has been previously described, would also be convenient on some occasions, and the outfit of tubs has already been spoken of. A bucket or water pail, especially one with a nozzle, will be found convenient in dipping up and pouring salt water for washing the collections.

When the dredger returns from an outing the dredge should be thoroughly cleaned and hung up where the air can get at it, so that it will dry thoroughly and the net and flaps will not rest anywhere upon the iron frame. By following these simple precautions a single net can be made to last a long time, but if rolled up while moist, or kept in a moist place, the net will often mildew and become worthless. These hints will be sufficient to start a collector in his dredging work. Each man, after some experience, will work out methods of his own or invent labor-saving devices or conveniences for use in his dredging work. All that the writer undertakes to do in the present case is barely to outline the mode of operations.

ON THE USE OF THE TOWING NET.

The towing net is an accessory to the collector's outfit which sometimes produces very desirable results in the way of collections. This can be used but little, except with a sailing vessel. The frame of the towing net is a circle of brass wire with four small loops of wire attached to it solidly, at equal distances apart (Figs. 7 and 8). To the frame is sewed a net made of cheese cloth, mosquito netting, or, preferably, of bobbinet. The border of the net, which is to be sewed over the brass ring, is best made of ordinary cotton cloth doubled and sewed over the wire. Between the doubled hinder edges of the cotton the bobbinet or mosquito netting may be fastened so as to form a conical net of the diameter of the ring and about 2 feet in length. If the netting is sewed directly over the wire it will give way much sooner than if cotton cloth is used for this part of it. To the loops referred to four small cords, ordinary cod line being a desirable size for the purpose, are securely fastened and knotted together in front of the ring, at a distance of about 3 feet.



FIGS. 7 and 8.—Towing net ring.

Care should be taken that they are exactly of the same length, so that when the net is suspended by the knot at that junction the ring will hang perfectly horizontal. In front of the knot is attached a line of suitable length, which may also be cod line, and this is made fast to the rail of the vessel. A sufficient amount of line is paid out to enable the net to drag evenly at the surface, with a small portion of the ring showing above the water. If too little line is paid out the net will jump and will not sink deeply enough to be of much service. If too much line is given to it it will sink too deep and lose those organisms which have the habit of floating on the surface. It is better to attach the towing net to the vessel's quarter rather than directly over the rudder, since refuse thrown overboard is very apt to drift in the ship's wake, and, if the net is towing directly aft, to drift into it. If the vessel is going at a moderate rate of speed there will be no difficulty in using the towing net. A little experience will show whether the circumstances are favorable for its use or not.

The mollusks obtained by use of the net are chiefly larval forms of gastropods, which float on the surface until they reach a more advanced stage of development—*Ianthina*, pteropods, and the so-called heteropods. True pelagic organisms are usually not found very near the shore, unless some ocean current strikes in toward the shore in the vicinity, but on short voyages, or long ones, large numbers of extremely interesting and usually very rare species may be obtained in this way. The length of time the net should be left over will depend upon the weather and upon the region traversed. In the tropics a short time will afford good results. In northern seas the net may sometimes tow for hours without many specimens being obtained. The most favorable time for its use is from a little before sunset to a short time after sunset, since many of these creatures seem to have the habit of coming to the surface at that time of the day and remaining at greater depths during the rest of the twenty-four hours. At the same time it may be noted that towing done at almost any time of day may produce good results, for all of the species do not have the crepuscular habit.

Many of these animals may be obtained alive, put into a tumbler of sea water, and preserved in a living state for a day or two at a time if the water is kept fresh. It is desirable that water-color sketches showing the form and coloration of these pelagic organisms should be made from life, as their tissues are very contractile and when preserved in alcohol shrink irregularly, so that the normal form is difficult to make out. With these mollusks will be obtained many curious crustaceans, and occasionally pelagic fish or fish larvæ and pelagic animals like Salpa and various medusæ, most of which are never found near shore. Several naturalists have experimented with towing nets which were made to be sunk below the surface, closing by a peculiar mechanism, so that at a given depth they could be opened in order to obtain animals proper only to that particular depth. These experiments, however, belong rather to the domain of deep-sea dredging and collecting, for information in regard to which the inquirer is referred to the works previously cited.

PRESERVATION AND PREPARATION OF COLLECTIONS.

After the collector has brought home the spoils of his excursion there is still a good deal to be done before the wet and dirty shells, covered with parasitic growths or inhabited either by the original mollusk or some hermit crab, will be ready to be placed in the cabinet. Some of them, if living, may find a temporary place in an aquarium for the study of their habits, but, for the most part, the collector will wish to prepare his specimens either for anatomical use in the future or as dry specimens for his cabinet. The preparation of mollusks for anatomical purposes has been described in a special chapter of these instructions. For ordinary rough work nothing is better than clean 90 per cent alco-

hol, diluted with a proper proportion of water. If the specimens are large they should first be put into a jar kept for that special purpose, in which the alcohol is comparatively weak, having, say, 50 per cent of water added to it. After the immersion of specimens in this jar for several days the fluids will have been extracted by the alcohol, and a specimen can then be removed, washed clean of mucus and dirt, which will almost always be found about the aperture of a spiral shell, and placed in its own proper jar of 90 per cent alcohol diluted in the proportion of about 30 per cent with pure water. Specimens to be prepared for the cabinet require the removal of the soft parts if they are still present, the cleaning off of parasitic or incrusting growths, and, in the case of bivalves, securing the valves in a convenient position for the cabinet. The different classes of shells may be treated of under several heads.

LAND AND FRESH-WATER SHELLS.

Land and fresh-water shells are much more easy to deal with than marine shells. In the case of spiral shells, such as *Limnæa*, *Planorbis*, *Paludina*, etc., the shell may first be washed clean of mud or comfervoid growth, which may be conveniently done with the assistance of an old tooth or nail brush. In the case of these forms the easiest way to remove the soft parts is to place the shell for twenty-four hours in weak alcohol, after which those parts can readily be removed; but in any case where the expense of alcohol is an object to be avoided, it will be sufficient to place them in a small tin kettle, or other receptacle suitable for the purpose, and cover them with cold water; which should then be slowly brought to the boiling point. As soon as it has reached the boiling point it may be removed from the fire. The shells should not be put into water already boiling, as it frequently cracks delicate shells, and the sudden change of temperature injures their polish and general appearance.

For removing the soft parts from spiral shells the collector will usually find a crooked pin sufficient. For this purpose one of those long steel pins used by ladies as hat pins is convenient. By heating the pointed end in the flame of a candle or alcohol lamp the temper can be taken out of the steel, so that it can be readily bent into any shape desired. The proper form for reaching the retracted parts in a spiral shell will of course be a spiral. With a small pair of plyers, different forms can be experimented with, and those which are most satisfactory decided upon. After the right form has been obtained, by heating the pin again and plunging it suddenly into cold water the temper of the steel will be measurably restored and the instrument ready for use. Similar pins in their ordinary condition are convenient for cleaning out sand or parasites from the recesses of sculptured shells, and for other purposes. The attachment of a gastropod to its shell is at the central axis or pillar of the shell, usually from half a turn to a turn and a

quarter behind the aperture. By applying the pressure of the extractor carefully in this vicinity the attachment will give way and the extractor may be withdrawn, bringing with it the soft portions of the animal. In large and heavy shells, in which the muscular attachments are strong and deep-seated and it is desired to obtain a good hold of the animal in order to extract it from the shell, ordinary steel fish-hooks may be used. These may be softened by heat, straightened out, and twisted into a spiral of the proper form, and retempered. Then they can be securely fastened to small wooden handles by the shank of the hook. In this way the barb of the hook will assist in retaining the soft parts on the extractor when it is withdrawn from the shell. Several German firms advertise sets of implements for cleaning, cooking, and extracting the animals from shells of mollusks, but it would seem to the writer that any person of ordinary intelligence and some little mechanical ingenuity, such as all naturalists are expected to possess, should be able to provide himself with the necessary apparatus without purchasing expensive paraphernalia of this kind. Shells which have no operculum require merely to be cleaned after the animal has been removed, and in the case of land and fresh-water shells this is usually a very simple matter. Shells which possess an operculum should retain it in the cabinet, as it is often of great value in determining the relations of the species, since the operculum is a characteristic feature in the economy of the animal. It should be detached from the body of the animal after the latter has been extracted from the shell, carefully washed and cleaned, and if flat and horny may be dried between two pieces of blotting paper, under a weight. This will prevent it from becoming contorted in the process of drying. For removing the thick incrustation of lime and peroxide of iron which frequently forms upon fresh-water shells, a few tools resembling engraver's tools or the little chisels in use by dentists for excavating teeth are very convenient. A suitable tool, however, can easily be made by softening and grinding down an old file to a triangular point. A little experience will enable the collector to become expert in scaling off the objectionable matter without injury to the surface of the shell.

Naked slugs should be preserved in alcohol, after being sketched in the living state. Some of the older naturalists had a way of skinning slugs, inflating and drying the empty skins for preservation in their collections, much as entomologists sometimes treat caterpillars; but this ingenious device has nothing to recommend it to a scientific collector, even if he has the dexterity to practice it. The internal shell of such slugs as *Limax* may be represented in the collection if desired, but, in any case, specimens should be carefully preserved in spirits.

The bivalve shells, such as *Unio*, if taken alive, may be left in the sun for a short time, when they will usually open, and, the muscle connecting the two valves being cut, the valves may be cleaned. It is desirable for cabinet purposes to preserve the two valves in their

natural position, attached to each other by the ligament which holds them together in life. This ligament dries to a very brittle, horny substance. Consequently the shells must be placed in position when fresh, in order to make a success of the operation. After cleaning away the animal matter and thoroughly washing the interior of the shell, it is a good plan to note the locality with a soft lead-pencil upon the shell itself. Then bring the two valves together in their natural position and tie them in that position with a piece of tape or soft twine, which should be allowed to remain until the ligament is thoroughly dry. Specimens prepared in this way are more valuable for exchange and more attractive to the eye than those with which less care has been taken. It is always desirable, however, to have some specimens with separated valves of every bivalve species in the cabinet, in order that the characteristics of the interior may be easily examined.

Fresh-water bivalves are usually covered with a thin and highly polished, often very elegant, greenish or brownish epidermis. Sometimes the shell is so thin that, in drying, the contracting epidermis splits and cracks the shelly portion so that it becomes worthless for the cabinet. This often happens with marine mussels, but is almost characteristic of the thin fresh-water *Unionidæ*. Various methods have been adopted to prevent this unfortunate result. Some collectors have varnished their shells immediately after they were obtained. Others have used sweet oil or other oils in the hope of keeping the epidermis in a soft condition. These applications are all objectionable for one reason or another, as the first endeavor of the collector who desires to make a really scientific collection should be to keep his specimens as nearly as possible in a perfectly natural condition. The most satisfactory substance for application to the shells in question is probably ordinary vaseline, which should be applied in very small quantities, so that the specimen will have no greasy feeling and will absorb the vaseline sufficiently not to become sticky to the touch. Glycerine, which has been recommended by several collectors, like oil, leaves the surface sticky and offensive to the touch, besides rendering it liable to catch everything in the way of dust with which it may come in contact.

Very small gastropod shells need not have the soft parts removed. If they are put into a vial of alcohol for twenty-four hours, then taken out and allowed to dry, the soft parts will become desiccated without any offensive odor, and they may be placed in the cabinet without further preparation. It may be noted, however, that if the cabinet contains many such shells, care should be taken to guard against the access of mice and vermin, which are apt to attack them in the absence of something more attractive in the way of food. For those shells which possess an operculum, after the operculum has been dried and the shell cleaned and ready for the cabinet it is customary to insert a little wad of raw cotton, rolled so as to fit the aperture snugly, the

outer surface of it being touched with a drop of mucilage. The operculum can then be laid upon this in its natural position and the mucilage and cotton will retain it so without making it difficult to remove for an examination of the shell, if desired at any time. For the preservation of eggs of mollusks when they have a horny or calcareous shell, small glass tubes securely corked are the best receptacles. Most of these eggs are so small that they may be preserved in a dry state or in alcohol without trouble, but the eggs of some of the tropical land snails are so large that it will be necessary to drill a small hole and extract the fluid contents as if they were bird's eggs in order to preserve them. Such eggs are best preserved in alcohol.

MARINE SHELLS.

The preparation of marine shells for the cabinet does not essentially differ from that required for land or fresh-water shells, except that in the marine shells the muscular system is often much more strongly developed and the creatures themselves much larger than the fresh-water forms, and the manipulation is therefore somewhat more difficult. The marine forms are also more apt to be incrusted with foreign bodies, bored by predatory sponges, like *Cliona*, or even by other mollusks, or perforated by certain annelids which have the power to dissolve the lime of which the shell is composed, and in this way secure a retreat for themselves.

Shells which do not contain the living animal are frequently occupied by hermit crabs or by tubicolous annelids. The latter fill up the larger part of the spire with consolidated sand or mud, in the center of which they have their burrow. The hermit crabs do not add anything to the shells which they occupy, but, on the contrary, by their constant motion are apt to wear away the axis or pillar of the shell, so that often a specimen of this sort may be very fairly preserved and yet on the pillar show characters entirely different from those which one would discover in a specimen which had never been occupied by a crab. A shell which the crab has selected for its home is often taken possession of, as far as the outside is concerned, by a hydractinia, a sort of polype, which produces a horny or chitinous covering which is very difficult to remove from the shell to which it is attached. As the hydractinia grows it finally covers the whole shell, to some extent assumes its form, and then, if the creature has not attained its full growth, this is apt to take place around the edges of the aperture, which are continued by a sort of leathery prolongation which assumes in a rough way the form of a shell. The crab, when he grows too large for the shell in which he has ensconced himself, is usually obliged to abandon it and find a larger one, which is always a difficult and more or less dangerous operation; but if his shell is overgrown by the polype referred to, it often happens that the polype and the crab grow at about an equal rate, so that the latter finds himself protected and does not have to make a

change. It is supposed that the polype profits to some extent by the microscopic animals attracted by the food or excrement of the crab, so that this joint housekeeping is mutually beneficial, and, for such cases, since the word *parasite* would not be strictly accurate, the word *commensal* has been adopted. These modified shells often assume very singular shapes. The polype is able in the course of time to entirely dissolve the original calcareous shell upon which its growth began, so that if the spire be cut through it would be found throughout of a horny or chitinous nature. Some of the older naturalists were deceived by forms of this sort and applied names to them, supposing that they were really molluscan shells of a very peculiar sort.

In removing the animal matter from the shell of large gastropods it will often require a good deal of time and care to get out all the animal matter from the spire, but it is well worth while to take the trouble, as the presence of such matter forms a constant attraction for museum pests of all descriptions. A medium-sized syringe is convenient for washing out the spire of such shells. The ordinary marine gastropods may be treated in a general way like the fresh-water gastropods. There are, however, abnormal forms, especially among tropical species, which require particular attention. Some species become affixed to corals and overgrown by them, retaining only a small aperture through which the sea water can reach the prisoner. Such specimens are best exhibited by retaining a part of the coral and cutting the rest away, showing at once the mode of occurrence and the form of the covered shell. Borers are always more difficult to handle and prepare for the cabinet than other mollusks. They are usually more or less modified for their peculiar mode of life, and frequently rely upon their burrow as a protection, so that the shell is reduced, relatively to the animal, to a very small size. Most of these forms are best kept in alcohol. The hard parts may properly be represented in the cabinet by other specimens. Some of the bivalves, such as the American "soft clam," possess very long siphons, covered with a horny epidermis, and it becomes a question as to whether an attempt should be made to preserve this epidermis in the cabinet or not. The writer has seen very nicely prepared specimens in which the fleshy portions had all been taken out and replaced by cotton, so that the epidermis of the siphon retained its original position and form; but such specimens are always very delicate, easily broken, and liable to attack by insects, so that it would seem hardly worth while to go to the trouble, when specimens may be preserved complete in alcohol showing all the features referred to. Boring shellfish, like *Pholas*, frequently have accessory pieces, which are liable to be lost when the soft parts are removed unless care is taken to avoid it. Other bivalves have the internal ligament reinforced by a shelly plate, which is called the ossiculum. This is very easily detached and lost, and, being an object of great interest, special pains should be taken to preserve it, even if it should become detached.

PRESERVATION OF SPECIMENS RESERVED FOR ANATOMICAL STUDY.

In these days the treatment of specimens intended for sectionizing or dissection has become an art in itself, as the wonderful results in morphological work abundantly testify. It would be impossible to go into such matters in detail, but in order that the collector may make the most of his opportunities the following brief directions have been kindly furnished by Prof. John A. Ryder, of the University of Pennsylvania.

DIRECTIONS FOR PRESERVING SOFT PARTS OF MOLLUSCA FOR ANATOMICAL USE.

Soft organisms should never be dropped into strong alcohol at once, as the rapid extraction of the water of organization by the alcohol shrinks the soft parts and distorts them. So, too, a too prolonged stay in too weak alcohol or spirits produces maceration or softening of the soft parts.

Fresh water gastropods are best treated so as to kill them as quickly as possible by drowning, which can be done by putting them in an air-tight vessel and filling the latter completely with water, so as to shut off all the air. The result of this treatment, after twenty-four hours or so, is that the soft parts after death are often more or less completely extended from the shell; then gradual hardening may be accomplished in alcohol of one part alcohol (95 to 97 per cent) and two parts water, for twenty-four hours, to be followed by further treatment with water and strong alcohol, equal parts, for twenty-four hours more. Final hardening may be accomplished in a mixture of two to four parts of alcoho. (95 to 97 per cent) and water one part, using the last and strongest mixture of alcohol to preserve the animals permanently. Soft organisms thus treated with gradually increasing strengths of alcohol usually give very excellent results, even for histological purposes. The sojourn of soft organisms in weak alcohol, if continued for too long a time, tends to produce maceration and dissociation of the cells. In such cases it is best to keep the jars in which the hardening and fixing is in progress in a refrigerator (if such a convenience is accessible) at a temperature of 45° to 55° for a day or two, or until the hardening has progressed far enough to avoid the chances of injurious maceration.

Paralyzing the larger mollusks with a 1 per cent solution of cocaine gives good results, but is somewhat troublesome. Under its influence gradual paralysis and death follow after one to three hours. The organism after such treatment may be gradually hardened in a fully extended condition in alcohol and water, gradually increasing the strength of the successive alcoholic solutions as recommended above.

A 1 per cent solution of chromic acid is most useful for bringing out surface details for the naked-eye inspection of the surfaces of soft parts, or their examination with low powers of the microscope. Organisms may be subjected for twenty-four hours to its action, after which they should be thoroughly well washed in running water for twenty-

four hours, until all the acid is removed. This washing is easily accomplished by putting the organisms in a jar with a wide mouth, over which a piece of coarse, cheap muslin or cheese cloth is tied; a small hole in the cloth may serve to permit passing a rubber hose, from any convenient water tap, into the jar, through which a gentle and constant flow of water may be thus maintained.

The addition of from one to one and one-half parts of acetic acid to every one hundred parts of the chromic-acid solution improves the result for histological purposes in cases where there are no calcareous parts to be injured and acted upon by the acids.

A very cheap and very excellent reagent for fixing and hardening the tissues of large mollusks is Müller's fluid. This may be made up as follows for gallon lots of the fluid: To every gallon of water take 3 ounces of pulverized bichromate of potash and 1½ ounces of sulphate of soda (Glauber's salts). These salts may, in fact, be powdered together in the quantities stated per gallon and put up in packages, each of which would thus contain 4½ ounces of the powdered and mixed salts, sufficient to make 1 gallon of the mixture. The salts should be completely dissolved in the water before using.

The action of this last reagent is slow and requires some attention, as do all of the processes given. Several volumes of the fluid should be used to a single volume of organisms or tissues. The hardening should be done in a cool, dark place. The fluid should be changed the first two or three days every day, then every other day, then twice a week, then once a week, till at the end of three to six weeks the hardening is completed, larger objects taking the longer time. It is also desirable to let the hardening go on in a dark closet or cupboard.

After the hardening in Müller's fluid the objects should be well washed with water, as recommended for chromic acid, under a tap in a jar covered with cheese cloth for twenty-four hours or more, according to the size of the objects. Objects hardened and fixed in Müller's fluid are almost or quite as good for the purpose of studying surface details as those hardened in chromic acid, and are as good for purposes of dissection as objects carefully hardened in alcohol.

After washing the objects hardened in Müller's fluid they should be placed in 70 per cent alcohol for permanent preservation. The 70 per cent alcohol is readily made with a sufficient approximation to accuracy by remembering that by adding nearly four-tenths of its volume of water to the ordinary 95 to 97 per cent alcohol of commerce an alcohol percentage of 70 is reached. Thus with an ordinary foot-rule the operator can mix his alcohols in cylindrical jars, thus:

Stand the jar upon the table, place the rule by the side of it with the scale next the glass, then pour in alcohol till some arbitrarily chosen tenth division of the rule outside is reached by the surface of the spirit, then add water to the spirit to the amount of nearly four more similar divisions of the rule, when the requisite dilution of 70 per cent approxi-

mately is reached. Shaking the mixture is all that is now required to mix the spirit and water, and the jar and its contents are ready for the reception of the materials treated with Müller's fluid.

The precautions given in the first paragraph of these directions in regard to the use and abuse of alcohol are vital, and no amount of after treatment of valuable material will atone for the neglect of the precautions recommended for the initial treatment. It is a thousand times better for a collector or a museum to have a little well-preserved material of a given type than bushels of poorly preserved material, literally "trash," of the same thing, that drops or breaks to pieces when the anatomist attempts to remove it from the jar. It is better, therefore, for the collector to take infinite pains with a smaller quantity of material to get it in the right condition with proper preservatives than to endeavor to make up in quantity what his collection may lack in quality.

As a final precaution, it is strenuously advised that too much material should never be packed into one jar or vessel to be fixed by a single bath of any given reagent. The volume of the first fixing and preserving reagent should always exceed by several times that of the objects to be fixed or hardened. This excess of the fixing and hardening reagents should be maintained until the hardening is completed. After the fixing and hardening is properly accomplished and the tissues of the objects have been thoroughly fixed and saturated with the reagents, then, and then only, may objects be packed together tightly with a relatively small amount of strong alcohol round them; otherwise, maceration may occur. In fixing and saturating large objects, especially if they contain large cavities, these should be opened and filled with the first fixing and hardening reagents by means of a cheap syringe made of glass, metal, or rubber.

The permanent preservative to be used after any of the hardening or fixing agents that are commended above should be 70 to 80 per cent alcohol, which is made by diluting ordinary 95 per cent alcohol with from four-tenths to about one-quarter of its own volume of water. Careful washing of the materials fixed and hardened in bichromate of potash or chromic acid is always to be enjoined before the objects are placed in the permanent preservative. This requires from twenty-four to forty-eight hours, according to the size of the specimens. Very small objects can be washed free from chromic acid or bichromate in a few hours by frequent changing or renewing the water over them. For large objects, over an inch in diameter, washing in a gentle current of water for twenty-four to forty-eight hours is advised before placing permanently in alcohol. When large gastropods are preserved in the shell and intended for anatomical examination, it is very necessary to admit the alcohol to the upper part of the spire by making a small hole with a file or other instrument in one of the upper whorls. Otherwise the delicate organs in this region can not be reached by the preservative fluid.

PRESERVATION OF THE RADULA.

The classification of gastropod mollusks has no more fundamental character among those upon which it is based than that of the radula. This is a strip or belt of chitinous or horny material occupying the place in the mouth where in vertebrates the tongue is found. Hence it is sometimes referred to as the tongue. The inner end of the radula is secreted by a glandular surface lining a pouch which lies under and behind the cartilaginous and muscular buccal mass upon which the radula is carried. The front end of the radula is strongly attached to the cuticle. The surface is usually set with teeth disposed in rows, transverse and longitudinal, each transverse row differing from that in front of it merely in maturity. The first few rows are brought into active use; the others form a reserve to come in play when the anterior rows are worn out. The buccal mass with the radula upon it is protrusile, and its action may be easily studied by feeding a snail with soft crumbs of bread or watching a Limnæa mowing away the green confervæ which gather on the glass of aquaria.

Some few gastropods have no teeth on the radula. A few others, like the cones, have isolated barbed teeth, to which a duct conveys poison from a venom-gland. The bite of a cone is extremely painful from this reason. The small round holes common in dead bivalves on the beach are drilled by predaceous gastropods, like *Natica* or *Urosalpinx*, who are able to use their teeth in a rotary manner.

In a few forms like *Acmæa*, *Patella*, and *Chiton* the teeth are less purely chitinous than in the land snails and most marine gastropods. Chitine is a substance very resistant to both acids and alkalies, especially the latter; so that, with few exceptions, such as those above named, the teeth may be boiled in caustic potash without injury. The horny jaw and its lateral appendages which exist in many gastropods will not, as a rule, survive such treatment, and must be dissected out, though in a few cases they are also chitinous.

In large gastropods the buccal mass with the radula upon it is easily recognizable, and can be dissected away without trouble. In rostriferous species it is in the muzzle, just within the mouth. In probocidiferous forms it is to be found at the retracted tip of the inverted proboscis. In the cones and Pleurotomoids, where the teeth are fewer and less compactly set, they are often found only by the exercise of great care.

In small species dissection is often out of the question and another method is to be used, which is, however, available only for such forms as have a decidedly chitinous radula. The radula of chitons and limpets subjected to boiling potash rapidly disintegrates, owing to the solution of the nonchitinous cement which holds the parts together. In such forms the radula must be sought with the aid of a microscope.

In the others the process is as follows: The student provides himself

with a microscope with objectives ranging from 1 inch to one-eighth inch, preferably those with a good deal of penetration, showing a large field rather than high magnification; two or three deep, old-fashioned watch glasses and test tubes; some caustic potash, an alcohol lamp, and a pair of spring forceps.

Extracting the animal from its shell, or simply crushing the latter gently, it is dropped into a test tube containing nearly a tablespoonful of caustic potash which has been allowed to attract the atmospheric moisture until it became liquid. Taking the test tube between the arms of the forceps hold it at the side of the flame of the alcohol lamp until it boils, being careful that it shall boil gently and shall not boil over; which, if held over the flame, it is likely to do. Watch that the animal matter is not thrown by ebullition out of the liquid on to the dry side of the tube. If this happens dislodge it by shaking the tube until the fluid washes down the object. Boil slowly and with patience until all the animal matter appears to be dissolved. Then, first shaking the liquid in the tube, pour it out quickly and steadily into a watch glass, replacing it by a little water, with which the tube should be rinsed and then emptied into another watch glass. Take the first watch glass and gently agitate the contents and when they are well stirred up give the glass a rotary motion, but not so violent as to spill the contents. This rotary motion will bring the solid particles in the potash to the center of the watch glass. A sheet of white paper under the watch glasses makes the search for the radula easier. The radula unless it is microscopic can usually be recognized by its curved elongated shape and apparently reticulated surface. It may be picked out on the point of a needle and transferred to a watch glass of clean water and washed clean of the potash. If microscopic the watch glass can be put on the stage of the microscope and examined with the 1-inch objective, when the search will usually reveal it. If it does not turn up examine the rinsings in the other watch glass, and lastly the test tube itself.

Having found the radula it may be laid in a drop of pure water and examined under a cover glass. The live box furnished with most microscopes is most convenient. Transmitted light with a Lieberkuhn reflector, or aided by a bull's-eye lens focussed above the cover, should be used.

After the general form and appearance of the radula has been noted and sketched or described, if an accurate knowledge of the teeth is desired, since they lie over one another like shingles on a roof, it is necessary to tear the radula up so as to get separate teeth, or rows, or parts of rows in full view. The whole can rarely be seen under one focus. The recurved cusp of the tooth being higher than the base both will not come in focus at the same time. Usually there are both small and large teeth in one series so that much caution is needed to make sure that everything has been seen.

Sometimes the teeth are very transparent and it is desirable to stain

them. To do this the radula after being carefully cleaned should be put in a drop of strong solution of chromic acid which stains it yellow brown. It will be seen to change color almost at once, and as soon as dark enough should be taken out and washed clean of the acid. If left in too long the acid may destroy the more delicate parts. It may then be treated as before suggested.

For a temporary mount glycerine jelly does very well. If Canada balsam is used it rapidly makes the teeth so transparent as to be invisible, and hence mounts in balsam should be stained. The writer has used hydrosilicon, which makes a very good mounting medium at first but in the course of time it becomes obscured by the formation of crystals.

The teeth are comprised in three principal longitudinal series, which are usually easily distinguished, though in some forms one or the other series may be absent or one lateral series may gradually merge into that next to it.

Normally there is a median longitudinal row of unpaired teeth, one tooth to each transverse row, with the series on either side symmetrical and similar on the two sides with the cusps inclined toward the center of the radula. This central tooth is known as the median or rhachidian tooth. On each side of the median tooth will be found a series of teeth varying in number but separated by their general form, and usually by a toothless space from a set or series of rows nearer the margin of the radula. The teeth of the series near the margin are apt to be small, simple, and similar to one another. In the *Trochidæ* they are very slender and numerous, almost like fur, and are in each row set upon a continuous solid basis which supports them all. These teeth are called the uncini, though other names have been improperly applied to them.

The less numerous but usually larger and more diversely formed teeth between the rhachidian tooth and the uncini, are called admedian or lateral teeth. In many forms one of these is much larger than the others and is known as the major lateral, while the others may be called the minor laterals. The teeth are simple, straight, curved, twisted or compound; in fact, the diversity is remarkable, but the characteristics for each group, especially genera and families or higher groups, are fully as permanent and important as are the teeth of vertebrates.

Any series may be wanting. The median tooth is often absent, and in at least one case the two adjacent laterals are known to have become consolidated, making a false or rather a compound median tooth. There are sometimes congenital deformities in the secreting glands. Such individuals may have an asymmetric or deformed radula. The cusps of the teeth being very brittle are easily broken off by too great pressure from the cover glass. The teeth are usually translucent, amber yellow, or dark brown. The cusps, especially of the major lateral, are sometimes black on a translucent base, as in *Chiton*.

The radula of *Litorina* and of *Patella* is very long and narrow. In

the Scaphopods (*Dentalium*) it is very short and broad. In most of the land shells the radula is curved so as to lie flat only under compulsion. In many marine forms the uncini are folded over and lie upon the admedian teeth, except those which are in active use.

The study of the radula is of the greatest interest and importance. Any shell containing the dried animal will probably afford the radula, as the chitine is nearly indestructible. A thorough study of the radula of our common fresh-water shells is still a desideratum and the student remote from the sea will need only to search the nearest ditch to find opportunities for making actual contributions to knowledge.

The work requires great care, patience, and a certain amount of experience. The beginner will do well to lay aside his first drawings and continue to practice. After a year has passed, if he will compare his slides with the drawings first made, he will better appreciate his own progress and the absolute necessity of caution in order to do good work.

In descriptions of the radula it is customary to use a formula called the *dental formula* to express the number and situation of the teeth. Each tooth is regarded as a unit and the different series are separated by a colon or period. Thus a radula with one rhachidian, three admedian, and twelve uncinal teeth would have as its formula 12 : 3 : 1 : 3 : 12. If it is desired to express the number of denticulations on the cusps of the teeth, the unit representing the tooth is written as a numerator and the number corresponding to the denticles as a denominator, while the fractions representing teeth belonging to the same class but differing in detail are connected by a plus sign (+), the series being separated by a colon as before.

$$\text{Thus } \frac{3}{1} : \frac{1}{4} + \frac{2}{2} : \frac{1}{3} : \frac{2}{2} + \frac{1}{4} : \frac{3}{1}$$

would represent the formula of a radula which had three single cusped uncini, a major lateral with four denticles on its cusp and two bicuspid minor laterals, on each side of a tricuspid rhachidian tooth. Since the admedian and uncinal teeth are bilaterally symmetrical, or similar, on each side of the rhachidian tooth, space is sometimes saved by writing the formula for the lateral or admedian teeth and uncini of one side immediately after that representing the rhachidian tooth. Thus 1 : 3 : 3 is the equivalent of 3 : 3 : 1 : 3 : 3. In cases when any of the series are absent their place is represented in the formula by a cipher, so 3 : 3 : 0 : 3 : 3 represents a radula in which the uncini and admedian teeth, to the number of three each, are present and the rhachidian tooth is suppressed, 3 : 0 : 1 : 0 : 3 represents a radula in which there are no admedian teeth and

$$0 : 0 : \frac{1}{3} : 0 : 0$$

one in which the dental armature is reduced to a tricuspid rhachidian series. Further modifications of this principal will suggest themselves with experience.

THE CABINET AND ITS FURNITURE.

CASES, TRAYS, AND TUBES.

The most convenient cabinet for the purposes of the collector of shells is one containing numerous shallow drawers in which the shells can be placed. Very elaborate cabinets of this sort are a luxury on which collectors and ordinary naturalists are seldom able to spend their money. Very convenient and entirely satisfactory cases, however, may be made with but little expense, in the following manner: Having first a plain outside case of suitable dimensions, to prepare it for the drawers let small straps of hard wood the length of the drawers be securely fastened horizontally at about an inch apart from the top to the bottom of the case on each side. These will form the rails upon which the drawers will run. The drawers having been prepared of different depths for the different sizes of shells, similar strips are fastened on them midway along each side. These strips run in the spaces between the strips nailed upon the outer case, and support the drawers. In this manner, all the drawers being of one size, differing only in depth, any drawer can be put into any part of the case. A deeper drawer can be intercalated between two shallow ones and so on, at the pleasure of the collector. The front of the case may be made of an ordinary sash door if the collector can afford it. Otherwise a wooden door may be used, but the edges against which the door shuts should be grooved to the depth of a quarter of an inch all around the doorway. On the door itself, so as to fit into this grooving, should be tacked small rubber tubing which, when the door is shut and securely fastened, will exclude the dust completely, and keep the collection in good order. Such a case as this is quite inexpensive, and if the collector obtains a large box, such as are used for the better class of packing cases, he can make a very satisfactory case for himself with the aid of a few strips of wood, screws, and a screw-driver. In order to exclude dust, which is a great enemy to most collections, if the case is not absolutely tight it will be well to paper it all over outside. This will improve its appearance if neatly done and make it perfectly dust tight. From such rude home-made appliances to the more elegant work of the professional cabinet-maker the collector may proceed as his means allow, but the principle upon which our home-made cabinet just described is constructed is the best one to follow, no matter how elegantly the work may be done. The principle of having all drawers interchangeable and of the same size, all trays multiples of a unit of size, and in general all parts based upon some fundamental unit of measurement or capacity, is that to which the best museums of the present day are universally tending. The convenience of the arrangement for the private collector is almost as great as for the public museum; since it in no way increases the cost it certainly is the best plan to follow.

For the representation of specimens inside the cabinet various plans have been adopted. The specimens may be kept in small trays, unless very small, when they may be put into glass tubes and closed with corks and these tubes into trays, or some system may be adopted by which specimens are mounted with cement on tablets, either of card, hard wood, glass, or even slate. There is no doubt that where space is of no importance and attractiveness in the collection is considered as preëminent, that specimens present a much more inviting appearance if mounted. For study, however, and for all scientific purposes mounted specimens are very undesirable. It is difficult to keep them clean, or if they become soiled to clean them. Glass can be washed, but no cement will adhere to glass for any length of time. Cardboard changes color, or if colored fades and after a time assumes a very shabby appearance. Wood is difficult to keep clean, although better than any of the others. The collector is advised therefore not to attempt to mount his collection. Many firms of paper-box manufacturers are prepared to furnish small paper trays without covers five-eighths of an inch deep and of such length and width as may be desired, at a very cheap rate. Those in most American museums are covered with white glazed paper, from which the dust can be easily brushed, and in width and length proceed on the basis of a unit of size, 1 inch by 2 inches. This is the smallest size of paper tray. All other sizes, except the next larger, which is 1½ by 2 inches, are multiples of the first In this way when the trays are put into a drawer they will fill it evenly, and if a cabinet is made to order the inside measure of the drawers should bear a suitable relation to the unit adopted for the paper trays to be put into them. For especially delicate specimens small boxes with glass tops are very desirable. These are, however, rather expensive luxuries, needed in most cases for few of the specimens ordinarily acquired by collectors. For small shells the glass tube, which is a sort of homeopathic vial without a neck and without any thickening around the aperture, is most convenient, and one may almost say indispensable. These are closed with corks. The tubes may be had from all dealers in glassware at a low price if specially ordered. As a rule they are not kept on hand. It is well to have them of several sizes. Those in use in the National Museum are of three diameters, three-eighths, five-eighths and 1 inch, and are of the uniform length of 1⅝ inches. This enables them to be corked and then placed in the smallest size of paper tray, and most shells which require to be tubed will be accommodated by these sizes.

LABELS.

The matter of labels is always of importance to the collector. The appearance of a collection depends very largely upon the neatness and uniformity of its labeling. Blank labels may be printed in sheets at very small expense and afterwards cut apart. They may have a heading, with the name of the collector and his place of residence, with a

space between the two items for the number of the particular lot recorded upon the label. Then three or four lines will afford space enough to write the name, locality and collector in most cases. These labels may be printed upon card, but for practical purposes stiff white paper, somewhat like writing paper, only a little thicker, is quite as good as card and much less expensive.

CATALOGUING.

The collector should keep a record or catalogue of his collection. Each specimen or set of specimens placed in it should be numbered and this number should be put upon the label. If the collection is large it would be advisable to number the shells themselves, which may be done with neatness and care in a manner which will not deface the specimens in any way. Small specimens contained in tubes may have a small slip of paper bearing the number included with them. In this way, if a drawer is overturned and the tubes fall out of the paper trays in which they have been placed, the proper locality of each tube can readily be restored, whereas if they were not numbered a certain amount of confusion and delay would result. As the collection grows larger a catalogue will be found to be almost absolutely necessary. The most convenient form for cataloguing comprises the registration book and what is called a card catalogue, which is, however, not necessarily made of cards. Slips of paper cut to a uniform size will do equally well although cards are rather more convenient. In the registration book should be entered as soon as practicable after the collection has been sorted and cleaned, the name of the specimen if known, otherwise its generic name (or in the absence of that a blank may be left to fill up afterwards) the locality, sex and depth, the season or date, and the collector's name. These will be entered in the register in the order of reception or such other as may be most convenient, no classification being admitted in the book. The same items, however, or such of them as is desired to retain, perhaps the name of the species and its registration number may suffice, would be written upon the card or slip which forms part of the card catalogue. These slips can then be arranged in any order, alphabetical or otherwise, which may be selected by the person concerned. By referring to the card the registration number can be easily found and all the details recorded in the register can be turned to without loss of time. These principles carried out to a greater or less extent are those upon which the collections of the best American museums are administered.

PACKING SPECIMENS.

A few hints on modes of packing may be useful for the collector:

Small shells in bulk may be simply put in to a box, such as mustard, tin, or a cigar box, filled so full that the contents can not shake about.

Larger specimens are best wrapped in paper, for which the thin brown paper used for wrapping oranges, or the so-called toilet paper, is excellent. For still larger specimens newspaper will do very well. The southern moss (*Tillandsia*) makes excellent packing material. Sawdust should be especially avoided in packing, as it is really worse than nothing.

In putting up glass jars or bottles containing specimens in alcohol, nothing is better than ordinary damp moss from the woods. The box should be lined with it, the jars set in so as not to touch each other at any point, and moss should then be carefully rammed down between them until the whole space is compactly filled, when a layer may be placed above the bottles and the box cover nailed down. As the moss dries in the box it makes a secure case for each jar, and the writer has shipped hundreds of jars many thousands of miles in this manner without a single breakage.

Boxes of moderate size travel better than very large or small ones.

For alcoholic specimens nothing is better than the screw-topped jars used for preserving fruit. Each jar should be carefully scrutinized to make sure that it it is in perfect order and screwed tight enough to avoid leakage. If the specimens do not fill the jar a handful of crumpled paper will serve as a buffer to prevent injurious friction. Jars should always be filled with alcohol to within an inch of the cover.

For the cabinet, stout vials with rubber corks are best, or jars with ground-glass stoppers for larger specimens. The latter are expensive and really less efficient than the screw-top jars, but of course present a better appearance.

In order that the identification of specimens shall not be lost, it is imperative that a label shall be inclosed in the jar itself. For jars which have to be transported long distances, a label of block tin is often used, upon which a number has been stamped corresponding to the collector's catalogue. Pure block tin in thin sheets can he had of dealers in assayer's supplies, and a set of numbered steel dies for stamping the numbers, of any dealer in hardware. Numbers printed on parchment are also used. Written numbers are apt to get worn off, but, if they must be used, it is best to write them on the best quality of stiff linen paper with a very soft lead pencil, the label being then wrapped up in a piece of clean manila paper to preserve it from wear. Such labels with good luck will last very well, but should, if possible, be supplemented by the tag of block-tin foil. Ordinary "tin," *i. e.*, tinned sheet iron, is entirely unfit for the purpose. Nearly all specimens contain some fatty matter and in cases where the strength of the alcohol is insufficient a chemical change takes place in that part of this fat which is combined with the alcohol, producing several ill-smelling ethers and fatty acids. Therefore nothing in the way of metal, ink, or other substances which may be affected by acid or ether should be inserted in any jar of specimens. Copper tanks with screw tops are sometimes used by collectors, but are

soon made leaky by oxidation of the metal unless thoroughly and completely coated inside with pure tin. When the latter, as is often the case, has been adulterated with lead, it is liable to oxidize and is little to be depended upon.

A method of packing identified species for transportation which has many advantages was invented by Dr. Stearns. He took old letters, discarded blank books, and other stiff paper and provided himself with a round stick about half an inch in diameter. Treating one side of the paper with flour paste he proceeded to roll the sheets compactly over his stick, which was then withdrawn, leaving tubes, which, when dry, were extremely solid and could be cut into suitable lengths with a sharp knife without collapsing. A wad of cotton in each end holds the shells safely in the middle of the short tube, while the data can be written on the outside. The economy and efficiency of this method, and its superiority to the average pill-box process have caused it to become popular wherever it has been introduced. The writer has even seen private collections kept in such tubes neatly made of white paper. Except for the larger species, the method is by no means the worst which could be mentioned.

BOOKS OF REFERENCE.

This is not the place for a general bibliography, but, as almost all requests for instructions to collectors are coupled with inquiries as to what books are available for their use, it is thought that a few references to general works may prove of advantage.

The scientific study of mollusks progresses so fast that no manual or text-book long remains up to the times in all particulars. The latest and most extensive general work on the mollusca is by Dr. Paul Fischer,* and is published in the French language. Indispensable for a student, it is somewhat too far advanced for a beginner, and less useful than a more elementary work for the average collector. A work which, notwithstanding deficiencies due to age and the later advances of the science, is still one of the best, if not the very best, English work to put into the hands of a beginner in Conchology is Woodward's Manual of Recent and Fossil Shells,† as it is familiarly called, which for many years has been a classic. Several editions have been published and it has had several publishers, but it is still on sale and can be obtained through any dealer in foreign books. The price is quite moderate, and the work will be found useful and still (apart from changes in classification) reasonably accurate.

A later work, convenient on account of its numerous figures, but

*Manuel de Conchyliologie [etc.]. Paris, F. Savy, 1887. 8°. Pp. 1369. 23 plates, 1,138 figures in the text.

†A Manual of the Mollusca, a Treatise on Recent and Fossil Shells [etc.], by Dr. S. P. Woodward. London, various publishers, 1856 to 1871. 8°, about 500 pp., and 24 plates.

more expensive, is Tryon's Manual of Conchology,* in three volumes, issued by the Conchological section of the Academy of Natural Sciences at Philadelphia.

Publications which were intended to serve the purpose of handbooks for students of our native mollusks have from time to time been issued by the Smithsonian Institution and the U. S. National Muséum. The older papers of this class are to some extent out of print, but may be obtained in most cases from dealers in second-hand books. The series has comprised the following memoirs:

Land and Fresh-water Shells of North America, by W. G. Binney and T. Bland. 8°, in three parts.

Part I. Pulmonata Geophila. 316 pp., 544 ill. in the text. 1869.

Part II. Pulmonata Limnophila and Thalassophila. 161 pp., 261 ill. in text. 1865.

Part III. Operculated Land and Fresh-water Species. 120 pp., 232 ill. in text. 1865.

The three parts comprise Smithsonian publication numbers 194, 143, and 144, respectively, and cover all the land and fresh-water gastropods except the melanians.

Researches upon the Hydrobiinæ and Allied Forms [etc.], by Dr. William Stimpson. 59 pp., 29 figures in the text. 1865.

This is chiefly devoted to the fresh-water Rissoidæ, and is No. 201 of the Smithsonian list.

Land and Fresh-water Shells of North America. Part IV. Strepomatidæ (American melanians), by Geo. W. Tryon, jr. 8°, 435 pp., 838 figures in the text. 1873.

This is Smithsonian number 253.

Monograph of American Corbiculadæ, recent and fossil [etc.], by Temple Prime. 80 pp., 86 figures in the text. 1865.

This is Smithsonian number 145, and includes an account of the American *Pisidium, Sphærium, Corbicula,* and *Cyrena.*

A Manual of American Land Shells, by W. G. Binney. Bulletin No. 28, U. S. Nat. Mus. 528 pp., 516 figures in the text. 8°. 1885.

This brings the subject of the Pulmonata, as treated in the "Land and Fresh-water Shells," up to date, though under a different arrangement.

Bibliographies of American Naturalists. II. The published writings of Isaac Lea, LL. D. By Newton Pratt Scudder. Bulletin U. S. Nat. Mus. No. 23. 8°. LX, 278 pp. and portrait. 1885.

In the absence of any general work on the American *Unionidæ,* this bibliographical index to Dr. Lea's works will be of use to students of the group.

A Preliminary Catalogue of the Shell-Bearing Marine Mollusks and Brachiopods of the Southeastern Coast of the United States [etc.]. By William Healey Dall, A. M. Bulletin U. S. Nat. Mus. No. 37. 221 pp., 74 pl. 1889.

This bulletin is devoted to the marine forms, which are illustrated by over 1,000 figures and tabulated so as to show their geographical and bathymetric distribution. The classification is revised and the tables are preceded by a bibliography comprising titles of works bearing on the mollusca of the region.

The nomenclature of the catalogue is extensively reformed over earlier usage, and the collector or student who desires to understand why many names have been changed or have disappeared will in most cases find the reasons fully stated in the following publications.

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* Structural and Systematic Conchology, an introduction to the study of the Mollusca, by Geo. W. Tryon, jr. Philadelphia, 1882–'84. 3 vols. 8°.

Bulletin of the Museum of Comparative Zoölogy at Harvard College. Vol. XII, No. 6. Report on the Mollusca [of the Blake expeditions]. By W. H. Dall. Part I. Brachiopoda and Pelecypoda. Cambridge, the Museum. 1886. 8°. pp. 171–318, pl. I–IX.

The same. Vol. XVIII. Part II. Gastropoda and Scaphopoda. Cambridge, the Museum. 1889. 8°. pp. 1–492, pl. X–XL.

These two publications incidentally review a large proportion of the marine mollusks of our southeastern coast. For a general index to the literature of mollusks for the same region the student may consult—

Bulletin of the U. S. Geological Survey No. 24. List of marine mollusks, comprising quaternary fossils and recent forms from American localities between Cape Hatteras and Cape Roque, including the Bermudas. By W. H. Dall, Washington, the Survey. 1885. 8°. 336 pp.

This bulletin also includes a bibliography.

For information in regard to the mollusks of the Pacific coast of the United States the collector is referred to—

Mollusks of Western North America. By Philip P. Carpenter, B. A., PH. D. Washington. Smithsonian Institution. 1872. 8°. XIV, 325 and 121 pp.

This comprises a bibliography to all papers published on this subject by Dr. Carpenter in foreign countries (but not his papers printed in America), a reprint of many of them and a general index to all, including those not reprinted, always excepting his American papers. It forms No. 252 of the Smithsonian list. A later list, which is, however, a mere list of names and localities, was printed by the State Geological Survey of California, as follows:

Geographical Catalogue of the Mollusca Found West of the Rocky Mountains, between latitudes 33° and 49° north. By J. G. Cooper, M. D. San Francisco. 1867. 4°. 40 pp.

If the student desires a general work in which all the species of mollusks are to be found figured, he is referred to the following publication, still in progress:

Manual of Conchology, Structural and Systematic, with illustrations of the species. By Geo. W. Tryon, jr. Continuation by H. A. Pilsbry. Philadelphia. Conchological section, Academy of Natural Sciences. 1882 to 1891 (*et seq.*).

This work is to be comprised in four series, of which the first and second are in progress, as follows: First series, marine univalves; second series, terrestrial mollusks; third series, marine bivalves; fourth series, fluviatile mollusks.

For reference to the scattered papers of earlier writers on American mollusks the following work will be found convenient, in spite of the want of an index:

Bibliography of North American Conchology previous to the year 1860. By W. G. Binney. Washington. Smithsonian Institution. 1863–4. 8°.

Part I. American authors. 650 pp.

Part II. Foreign authors. 298 pp.

These form numbers 142 and 174 of the Smithsonian list.

In conclusion, it may be added that many of the American recent mollusks, which are also found fossil, and which are not illustrated elsewhere, may be found figured in the Transactions of the Wagner Free Institute of Science, Philadelphia, Pa., Vol. III.